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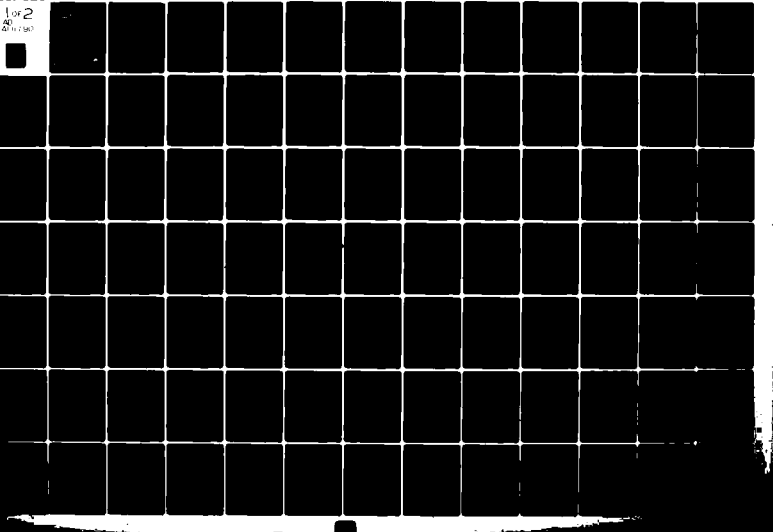

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USAFSAM REVIEW AND ANALYSIS OF RADIOFREQUENCY RADIATION BIOEFFECTS LITERATURE

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November 1981

Interim Report for Period 1 March 1980 - 31 August 1980

Prepared for
USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This interim report was submitted by SRI International, 333 Ravenswood Avenue, Menlo Park, California, under contract F33615-80-C-0608, job order 7757-01-73, with the USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas. James H. Merritt (USAFSAM/RZP) was the Laboratory Project Scientist-in-Charge.

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed is approved for publication.

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The objectives of this project are to acquire, review, and analyze, on an ongoing basis, information on research pertaining to the biological effects of radiofrequency radiation (RFR), for the U.S. Air Force School of Aerospace Medicine (USAFSAM). The method in use is to: (1) select documents that are, in our judgment, representative of prior and current research on various RFR-bioeffects topics, (2) analyze in detail the contents of each such document, (3) assess the validity and the significance of

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20. ABSTRACT (Continued)

the results presented, and (4) summarize periodically the current status of research on each major topic. In this report, the major RFR bioeffects topics are listed, and the format being used for analyzing each selected document is described. At present, the text of each analysis is being prepared and submitted to USAFSAM in optical character recognition (OCR-B) font, to permit direct storage of the information in a computer at USAFSAM. During the period covered by this report, a total of 60 analyses have been completed, of which 49 are in OCR-B font, and copies of which are included in the Appendix. The Appendix also contains a summary of the current status of epidemiologic studies of RFR bioeffects.

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FIGURES

Figure

USAFSAM REVIEW AND ANALYSIS OF RADIOFREQUENCY RADIATION BIOEFFECTS LITERATURE

INTRODUCTION

The objectives of this project are to acquire, review, and analyze, on an ongoing basis, information on research pertaining to the biological effects of radiofrequency radiation (RFR), and to provide periodic technical reports of our findings and assessments to the USAF School of Aerospace Medicine (USAFSAM) in specified formats.

The first interim technical report is for the period from 1 March through 31 August 1980.

METHODOLOGY

Thousands of scientific papers, reports, books, summaries, and abstracts (referred to collectively as "documents") have been published on the bioeffects of RFR and related fields. References to most of these documents are readily available through the various abstracting services. Therefore, needless duplication of such services will be avoided. Instead, the approach being pursued in this project is to: (1) select documents that are, in our judgment, representative of prior and current research on various RFR-bioeffects topics, (2) analyze in detail the contents of each such document, (3) assess the validity and the significance of the results presented, and (4) summarize periodically the current status of research on each major topic.

The intent is to prepare the analysis of each document in a format that permits easy storage of the information in a computer at USAFSAM and retrieval of each entire analysis by means of any of several coded designators, e.g., by major topic, frequency, modulation (pulsed or CW), species, etc. Thus, it will be possible to use any specific designator code to search for and retrieve all of the analyses pertinent to that designator. At present, the text of each analysis is being prepared and submitted to USAFSAM in an optical character recognition (OCR-B) font, to permit direct storage of the information without retyping. The software for subsequent retrieval is being developed by USAFSAM.

A list of the major topics under study (selected by agreement with USAFSAM) is shown in Figure 1. The numerical designator preceding each topic was assigned arbitrarily for coding purposes. Some topics include more specific subheadings as appropriate. For example, the "RFR auditory effect" is a subheading of "Nervous

1 Epidemiologic
2 Mutagenic and cytogenetic
3 Teratogenic and developmental abnormalities
4 Ocular
5 Nervous system
6 Behavioral
7 Endocrinological
8 Immunological
9 Biochemical/physiological
10 Cellular
11 Mechanisms of interaction
12 Environmental
13 Medical applications
14 Review
15 Ecological
16 Physical methods/dosimetry
17 Other
18 Drug interactions

Figure 1. Type of study.

Authors:
Title:
ISSN and citation:
Study type: (code and topic; in vivo/in vitro; species)
Effect type:
Frequency/wavelength:
Modulation:
Power densities:
SAR:
Exposure conditions:
Author abstract or reviewer summary:
Other information:
Initial or final critique:
References:

Figure 2. Outline form for analyses.

system." However, assignment of numerical designators for such subheadings is not contemplated at present.

The basic outline form being used for analyzing each document is shown in Figure 2. The authors, title, and publication citations are given in one of the formats commonly used. In addition, if an International Standard Serial Number (ISSN) has been assigned to the document and is available, it is included with the citation. However, it should be noted that the manner in which ISSNs are assigned varies with the publication. To illustrate this point, the paper by O. P. Gandhi, "State of the Knowledge for Electromagnetic Absorbed Dose in Man and Animals," Proc. IEEE, Vol. 68, No. 1, pp. 24-32 (Jan 1980), has been assigned the ISSN 0018-9219/80/0100-0024, in which the first eight digits represent the journal and the next two the year of the issue. The next four digits represent the number or month of the issue and the last four the first page of the paper. Similarly, the paper by A. W. Guy et al., "Circularly Polarized 2450-MHz Waveguide System for Chronic Exposure of Small Animals to Microwaves," Radio Sci., Vol. 14, No. 6S, pp. 63-74 (Nov-Dec 1979), has been assigned the ISSN 0048-6604/79/1112-S010, in which the first ten digits have the same meaning as before. However, the next four represent the months rather than the issue number, and the last group of four symbols indicates that the issue is a supplemental one and that the paper is the tenth one in the issue (rather than the first page of the paper).

For each document under review, one or more pertinent major topics, preceded by their numerical designators (from Figure 1) are listed under "Study type." All important relevant topics are included to ensure retrieval under any one of them. If a subheading is appropriate, it is also shown, e.g., (5) Nervous system (calcium efflux). In addition, whether an experimental investigation was performed in vivo or in vitro and the species studied are also shown under this heading.

The specific effects, phenomena, biological endpoints, or other characteristics sought or studied are listed under "Effect type," e.g., "thresholds for auditory perception of RFR." The next four headings are self-explanatory. Information such as duration of RFR exposure, type of exposure facility, RFR characteristics, and other pertinent data is given under "Exposure conditions."

The analysis per se begins with a verbatim reproduction of the abstract provided by the authors if the document includes one, and we use the heading "Author abstract" to indicate this fact. Under "Other information," we then summarize any important information in the text of the document that was not included in the abstract, and cite previous work by the authors or research by others on the same topics, if pertinent, but without commenting on such information. If the document does not contain an abstract, then we summarize its important contents in detail without comment,

and we indicate this fact by using the heading "Reviewer summary." Any pertinent information not appropriate for the summary is given under "Other information."

If the document contains sufficient information to permit it, a detailed critique of its contents is given under the heading "Final critique." To the extent possible or appropriate, our critique includes analysis and evaluation of: the data presented, the biological and engineering methodology used, the validity of the results, how the findings compare with those of other investigations, and the significance of the findings with respect to the health of humans (and/or other species) exposed to RFR. If the document contains information of sufficient importance to merit review, but lacks basic information needed to perform an adequate critique, then we so state and use the heading "Initial critique," with a view toward seeking or awaiting the additional information necessary for a final critique.

If we allude to any other documents as part of our analysis, then these are listed under "References." Complete analyses (in OCR-B font) of various papers, illustrative of this methodology, are contained in the Appendix to this report.

PROGRESS DURING THE FIRST HALF YEAR

The early part of the period was devoted primarily to the development of a suitable format and procedure for performing document analyses and storing them in the USAFSAM computer. These efforts led to the adoption of the outline form shown in Figure 2 and to the use of OCR-B font in the preparation of final copies of the analyses. After completing a group of analyses, they are typed into our word processor, proof copies are obtained and corrections entered, and final copies in OCR-B font are produced for delivery to the USAFSAM.

Concurrent with the development of methodology, we began to acquire recently published documents not already in our possession and to perform analyses on selected documents. In view of the large number of documents already available at SRI, we decided that it would be most productive to prepare an initial base of analyses in each major topic by selecting and analyzing already published journal articles, which, in our judgment, yielded significant positive or negative findings in that topic or were otherwise seminal.

By the end of the period, we had performed a total of 60 complete analyses, of which 43 were in final format (OCR-B font) and were delivered to the USAFSAM on 18 September 1980 for comment and/or storage in the USAFSAM computer. The remaining 17 were in written form awaiting typing into our word processor, and 6 of these have since been processed. Our work schedule did not permit us to start analyses of documents pertaining to all of the major topics,

so we deferred starting those having, in our judgment, relatively low priority. We expect to complete the initial base of analyses early in the second half of the year. When we do, our intent is to augment the information on each topic on an ongoing basis by selecting and analyzing publications, reports, books, abstracts, and presentations that are more recent than those included in the initial base.

The 49 analyses completed thus far in final format are listed and included under their respective topics in the Appendix. Analyses of documents pertaining to more than one topic are listed under all appropriate topics but are not duplicated. Instead, reference is made to the topic under which the analysis is included.

We have also begun preparing brief collective summaries of the state of knowledge of each major topic. We will complete these summaries by the end of the second half year, based on the analyses performed by then and on our prior and current knowledge of studies not analyzed in the prescribed format. To illustrate the format of such summaries, we have also included the summary completed on Epidemiology in the Appendix (preceding the analyses under that topic).

PLANS FOR THE SECOND HALF YEAR

We will complete the initial base of analyses early in the second half of the year while concurrently continuing to acquire recent documents.

We will continue to perform detailed analyses of important publications, reports, books, abstracts, and symposia presentations to augment the initial base during the remainder of the period, and will assess and summarize the then state of knowledge on each topic.

We will attend important symposia and other meetings devoted to the bioeffects of RFR to the extent permitted by available funds. (Messrs. Heynick and Krebs attended the Second Annual Meeting of the Bioelectromagnetics Society in San Antonio, Texas, 14-18 September 1980.)

APPENDIX

ANALYSES OF MAJOR RFR-BIOEFFECTS TOPICS PERFORMED DURING THE FIRST HALF YEAR AND SAMPLE COLLECTIVE SUMMARY

CONTENTS*

*The number in parentheses is the classification under which the topic is filed.

CONTENTS (concluded)

APPENDIX

ANALYSES OF MAJOR RFR-BICEFFECTS TOPICS PERFORMED DURING FIRST HALF YEAR AND SAMPLE COLLECTIVE SUMMARY

(1) EPIDEMIOLOGIC

Retrospective epidemiologic studies have been carried out to ascertain whether one or more health-related conditions could be associated statistically with chronic exposure to RFR. Although the exposures involved could not be defined well in terms of RFR characteristics or exposure durations, the studies do provide almost the only direction information available on possible effects on humans of RFR exposure.

To date, we completed analyses of 12 representative epidemiologic studies exclusive of those dealing primarily with RFR cataractogenesis (which are included separately under "Ocular"). These 12 studies are assessed individually and collectively below, followed by the analyses of each per se.

Collective Summary

In Lilienfeld et al. (1978), the purported effects of irradiation of the U.S. Embassy in Moscow were studied by comparing the health of U.S. personnel and dependents assigned to that embassy with those assigned to other Eastern European embassies. They found no convincing evidence that such RFR exposure (up to 18 $\mu W/cm^2$ maximum average power density) affected the health status of those at the Moscow embassy. Although there were several limitations in the study, which were recognized by the investigators, we believe that their findings of no RFR-related increases in mortality or morbidity are valid.

Sigler et al. (1965), in studying 216 cases of Down's syndrome (Mongolism) and matched controls in Baltimore, found an association between the occurrence of this malady and the presumed

exposure of the fathers to RFR from radars. In a later study by Cohen et al. (1977), the original data of Sigler et al. were reexamined together with data on 128 additional matched case-control pairs. They found no statistically significant differences in the occurrence of Mongolism among progeny of fathers who were probably exposed to RFR and those who were probably not, and it seems likely that the positive finding in the original study was a statistical anomaly. However, the difficulties in determining differences in RFR exposure between case and control fathers by military records and interviews renders the validity of these studies inconclusive.

Robinette and Silverman (1977) compared mortality and morbidity data for about 20,000 Naval veterans of the Korean war who were assumed to have been occupationally exposed to RFR on the basis of their military occupational titles with about 21,000 veterans assumed to have not been occupationally exposed. They found several statistically significant mortality differences between the two groups, but indicated that these differences could not be interpreted as being a direct result of RFR exposure. No results on morbidity were given. The two groups compared in this study are adequate in size for statistical treatment but should be characterized as a high-exposure and a low-exposure group, which vitiates the conclusions to some extent. Nevertheless, the findings indicate that the high-exposure group did not suffer higher mortality because of RFR exposure, and that the death rates for both groups were lower than those for the comparable age groups in the U.S. population at large.

In a study by Peacock et al. (1971) birth certificates filed during 1969-1970 from Dale and Coffee Counties, Alabama, in which Fort Rucker is located, showed a larger number of clubfoot cases than the expected statewide incidence, and a more detailed study of this and other congenital anomalies in the six counties surrounding Fort Rucker showed higher incidences among offspring of military personnel than for the state as a whole. Burdeshaw and Schaffer (1977) examined the Alabama anomaly data for 1968-1972 in detail, using more appropriate statistical treatments and

information on 46 Alabama hospital characteristics and reporting procedures. Most of their findings indicate that the anomaly incidence rate in the Fort Rucker area is not unusually high, but that most of the counties having anomaly rates in the upper quartile were in a contiguous band, indicating the existence of a geographically distributed anomaly problem. On an overall basis, they stated that it could not be concluded that an unusually large number of infants having congenital anomalies were born to military personnel at Fort Rucker or to other residents in its vicinity. We believe that the geographically distributed birth anomaly problem in Alabama may be due to other factors than exposure to RFR.

Siekierzynski (1974) compared the health status and fitness for work of 507 persons in Poland occupationally exposed to pulsed RFR exceeding 0.2 mW/cm^2 average power density (other RFR characteristics not specified) with a group of 334 workers at the same installations exposed to less than 0.2 mW/cm^2. Clinical tests included ophthalmoscopic examination and a neurologic check-up supplemented by psychologic tests and EEG recordings. No statistically significant differences between the two groups were found. In our opinion, the lack of more definitive RFR exposure data vitiates, but does not invalidate the negative findings of this study, i.e., the results provide no evidence for RFR-induced effects on the health status of either group.

Kalyada et al. (1974) clinically examined a group of specialists in the USSR working with RFR generators in the 40-200 MHz range for one to nine years and reported frequency occurrences of functional changes in the central nervous system described as vegetative dysfunction accompanied by neurasthenic symptoms. No organic lesions were found, but among the many specific changes reported were deviations in the physiochemical and functional properties of erythrocytes and leukocytes. They also conducted experiments with human volunteers and reported functional changes in the thermoregulatory and hemodynamic systems and in the thermal, optical, and auditory analyzers. However, no RFR intensity values

were given for either the specialists or the volunteers, and most of the findings were presented in narrative form, with no actual data, and the nature of the control group studied was not described. Consequently, this paper provides little if any useful information to affirm or deny the occurrence of possible adverse effects of occupational exposure to RFR.

Klimkova-Deutschova (1974) surveyed various industrial worker populations in Czechoslovakia, including metal welders, steel factory workers, plastic welders, technicians operating radio or television transmitters, and people working in research institutes and other industries that involve exposure to RFR. Miscellaneous administrative staff members were studied for comparison. Frequencies varied according to the place of exposure, ranging from 0.5 to 150 MHz, 300 to 800 MHz, or 3 to 30 GHz. The power densities, where specified, ranged from 0.1 to 3.3 mW/cm^2. A sample of 352 workers was selected from 530 people considered. The findings included electroencephalographic disorders (consisting of synchronized waves of high amplitude and slow rhythm) and biochemical changes (such as elevation of fasting blood glucose, serum beta-lipoprotein, and cholesterol). Changes in brain-wave patterns and in blood sugar, protein, and cholesterol levels were described as more pronounced in the people exposed in the 3- to 30-GHz range. Although the author states that differences among groups for specific manifestations were either statistically significant (at the 0.05 or 0.01 level) or were not, numerical results or their statistical treatment were not given.

Sadchikova (1974) presented clinical observations on the health status of two groups of USSR RFR workers. Those in the first group (1000) were exposed to up to a few mW/cm^2, whereas those in the second group (180) were exposed to values rarely exceeding several hundredths of a mW/cm^2, both at unspecified "microwave" frequencies. A group of 200 people of comparable backgrounds other than RFR exposure served as controls. Sixteen kinds of symptoms were reported, including fatigue, irritability,

sleepiness, partial loss of memory, bradycardia, hypertension, hypotension, cardiac pain, and systolic murmur. In the higher-power-density group, the incidences were higher than in the lower-power-density group for five of the 16 symptoms, lower for nine symptoms, and about the same for the remaining two. Incidences in the control group were lower than those in either exposed group for 15 of the 16 symptoms. A few subjects of the first group who worked under unspecified "unfavorable" conditions developed cataracts. Although bar graphs were included that show percentages of changes in the 16 symptoms among the 3 groups, statistical treatments of the data were not provided, so whether any of the reported differences were statistically significant cannot be ascertained. The occurrence of cataracts in the few who were working under "unfavorable conditions" must be interpreted as an indication of exposure to power densities well in excess of the cataractogenesis threshold.

Pazderova (1971) reported on the results of a battery of medical evaluations carried out on 58 employees of Czech television transmitter stations. Exposure frequencies were estimated to range from 48.5 to 230 MHz at field intensities equivalent to 0 to 22 $\mu W/cm^2$, with a mean exposure duration of 7.2 years (10.6 hours/workday). Electrocardiograms, heart and lung X-rays, erythrocyte sedimentation rates, urinalyses, and liver function tests were conducted as well as hematologic, serologic, ophthalmologic, neurologic, gynecologic, psychiatric, and psychologic examinations. The only statistically significant finding was that the mean plasma protein levels were higher than "normal" values taken from the literature, a finding that even the author finds unexplainable. The appropriateness of the use of literature control values is highly questionable. In a later study by Pazderova et al. (1974), the effects of RFR on blood protein ratios were reexamined. In the 60- to 300-MHz range, 51 people were exposed to fields up to about 0.02 mW/cm^2; in the 3- to 30-MHz range, 19 people were exposed to about 1 mW/cm^2; and in the 640- to 1500-kHz range, 39 people were exposed to about 0.8 mW/cm^2. A group of 59 workers

served as controls, but the authors indicate that the only difference between exposed and control groups was that those included in the exposed groups had worked in irregular shifts whereas more than half of the control people had only worked morning shifts. The results showed that the levels of blood proteins and their fractions were within normal physiologic limits, both the mean and individual values, but statistically significant differences were found between mean values for the exposed and control groups. In our opinion, the absence in either study of a control group that had received virtually no RFR exposure renders questionable that any differences found were due to RFR exposure. It is likely that the altered values of blood proteins (which were within normal limits) were due to other factors.

In overall summary, none of the U.S., Polish, and Czechoslovakian studies analyzed thus far offer evidence of detrimental effects associated with exposure of the general population to RFR. Consistent with the voluminous, earlier Soviet literature, the Soviet studies offer findings that occupational exposure to RFR at average power densities less than 10 mW/cm^2 does result in various symptoms, particularly those associated with CNS disorders. Because the USSR symptomatology has never been reported in Western studies and because there are marked differences between Soviet and Western publications in the procedures used for reporting data, any prediction of possible RFR hazards based on the USSR epidemiologic studies would require acceptance of these Soviet findings at face value.

(1) EPIDEMIOLOGIC

List of Analyses

Appleton, B., S. Hirsh, R. O. Kinion, M. Soles
G. C. McCrossan, and R. M. Neidlinger,
MICROWAVE LENS EFFECTS IN HUMANS
Arch. Ophthalmol., Vol. 93, pp. 257-258 (1975) (See "Ocular" for analysis.)

Burdeshaw, J. A. and S. Schaffer
FACTORS ASSOCIATED WITH THE INCIDENCE OF CONGENITAL ANOMALIES: A LOCALIZED INVESTIGATION
Final Report, Report No. XXIII, 24 May 1973-31 March 1976, Contract No. 68-02-0791, EPA 600/1-77-016 (March 1977)

Cleary, S. F. and B. S. Pasternack
LENTICULAR CHANGES IN MICROWAVE WORKERS--A STATISTICAL STUDY
Arch. Environ. Health, Vol. 12, pp. 23-29 (1966) (See "Ocular for analysis.)

Cleary, S. F., B. S. Pasternack, and G. W. Beebe
CATARACT INCIDENCE IN RADAR WORKERS
Arch. Environ. Health, Vol. 11, pp. 179-181 (1965) (See "Ocular" for analysis.)

Cohen, B. H., A. M. Lilienfeld, S. Kramer, and L. C. Hyman
PARENTAL FACTORS IN DOWN'S SYNDROME-RESULTS OF THE SECOND BALTIMORE CASE-CONTROL STUDY
In E. G. Hook and I. H. Porter (eds.), POPULATION GENETICS-STUDIES IN HUMANS, Academic Press, New York, pp. 301-352 (1977)

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHZ RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION. Polish Medical Publishers, Warsaw, pp. 52-57 (1974)

Klimkova-Deutschova, E.
NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 268-272 (1974)

Lilienfeld, A. M., J. Tonascia, S. Tonascia, C. H. Libauer, G. M. Cauthen, J. A. Markowitz, and S. Weida
FOREIGN SERVICE HEALTH STATUS STUDY: EVALUATION OF HEALTH STATUS OF FOREIGN SERVICE AND OTHER EMPLOYEES FROM SELECTED EASTERN EUROPEAN POSTS
Final Report, July 31, 1978, Contract No. 6025-619073, Dept. of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, MD (1978)

Pazderova, J.
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)
Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, pp. 265-271 (1971). English translation: JPRS No. UDC 616-001.228.1-057-07 (1971)

Pazderova, J., J. Pickova, and V. Bryndova
BLOOD PROTEINS IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING STATIONS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 281-288 (1974)

Peacock, P. B., J. W. Simpson, C. A. Alford, Jr., and F. Saunders
CONGENITAL ANOMALIES IN ALABAMA
J. Med. Assoc. Ala., Vol. 41, No. 1, pp. 42-50 (1971)

Robinette, C. D. and C. Silverman
CAUSES OF DEATH FOLLOWING OCCUPATIONAL EXPOSURE TO MICROWAVE RADIATION (RADAR) 1950-1974
In D. G. Hazzard (Ed.), SYMPOSIUM ON BIOLOGICAL EFFECTS AND MEASUREMENT OF RADIOFREQUENCY/MICROWAVES, Dept. of Health, Education, and Welfare, Washington, D.C., HEW Publication No. (FDA) 77-8026 (1977)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974)

(1) EPIDEMIOLOGIC

List of Analyses (continued)

Siekierzynski, M.
A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 273-280 (1974)

Sigler, A. T., A. M. Lilienfeld, B. H. Cohen, and J. E. Westlake
RADIATION EXPOSURE IN PARENTS OF CHILDREN WITH MONGOLISM (DOWN'S SYNDROME)
Bull. Johns Hopkins Hosp., Vol. 117, pp. 374-395 (1965)

Analyses under

(1) EPIDEMIOLOGIC

Burdeshaw, J. A. and S. Schaffer
FACTORS ASSOCIATED WITH THE INCIDENCE OF CONGENITAL ANOMALIES: A LOCALIZED INVESTIGATION
Final Report, Report No. XXIII, 24 May 1973-31 March 1976, Contract No. 68-02-0791, EPA 600/1-77-016 (March 1977)
Study type: (1) Epidemiologic, (3) Teratogenic and developmental abnormalities;IN-VIVO;HUMAN
Effect type: RFR-induced congenital anomalies among white and black populations
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Unknown
REVIEWER SUMMARY: In this report, the Alabama birth record data studied previously by Peacock et al. (1971) were reexamined for possible RFR-related anomalies. Instead of using statewide averages as a control for county incidences, the authors compared the Coffee and Dale County data (in which Fort Rucker is located) with those of each of the other 65 Alabama counties on a score and rank basis. They also sent questionnaires to 46 Alabama hospitals to acquire more detailed information on hospital characteristics and reporting procedures to permit prediction of expected values for Lyster Army Hospital in Fort Rucker. They found the following evidence against the conclusion that there is an unusually high anomaly incidence rate in the Fort Rucker area:
1. During the study period July 1968-December 1972, the overall rates for Coffee and Dale Counties rank only sixth and eighth among the 67 counties in Alabama.
2. Although the two highest rates in a sample of 47 hospitals are 17.7 at Lyster Army Hospital, Fort Rucker, and 18.0 at the Air Force Base in Montgomery County, there are five other hospitals in the Alabama sample that have rates between 12.2 and 14.5. There is no statistically significant difference between these rates and Lyster's.
3. Prediction intervals show that Lyster's overall rate is well within what would be expected from a hospital with Lyster's characteristics.
4. When the addresses of the mothers of anomalous infants were plotted on county road maps, no significant clustering, especially in the vicinity of presumed radar sites, was apparent.
5. The rates, by International Classification of Diseases category, from Lyster seem to be consistent with rates obtained from carefully controlled studies, such as one reported recently from Mayo Clinic. Because there is no reason to believe that Mayo's rates are unusually high, they should serve as a reasonable "normal control" for the Rucker study.

6. When the occurrences of anomalies within categories with the highest rates at Lyster are plotted on a time axis, significant clustering is apparent. There is evidence that, in most cases, the reporting of anomalies within a cluster may be attributable mainly to one or two physicians, rather than to the several physicians on the staff at any one time.
However, they cite two observations that prevent the dismissal of the anomaly question:
1. The two highest rates from the hospital survey, at Fort Rucker and Maxwell AFB, are both from military installations and aviation centers. These rates cannot be explained easily by the fact that military hospitals are more alert to the presence of an anomaly, because the rates at Redstone Arsenal and Fort McClellan in Alabama are 7.1 and 0.7, respectively.
2. Thirteen of 17 counties with overall rates in the upper quartile lie within a contiguous band that has one terminus in Houston, the south-easternmost county in Alabama, and that extends west-northwesterly to Marengo, one county removed from the Mississippi state line. The 20 counties in the southeast quadrant of Alabama have ten counties in the upper quartile, and this is more than can be explained by chance. This phenomenon, however, may involve more than a "military base" explanation.
Their overall conclusion was that on the basis of the birth record data, it could not be concluded that an unusually large number of infants with congenital anomalies were born to military personnel at Fort Rucker or to other residents in the immediate area.
OTHER INFORMATION: In November 1973, Peacock, Williams, and Nash submitted a report to the EPA from the Southern Research Institute based on both a reexamination of the birth-record data included in the 1971 report of Peacock et al., and examination of additional birth records so that a four-year period from 1968 to 1972 was covered. They found that, on the basis of the four-year data and after making adjustments for "non-radar" factors, the Lyster Hospital anomaly rates in several categories were abnormally high for all anomalies, heart, genital organs and musculoskeletal categories, and that the evidence was strong that the rates were also abnormally high for fetal deaths, circulatory and respiratory systems, cleft palate, and in the skin-hair-nail categories. Eglin AFB Hospital fetal death rate was nearly identical to that for Lyster Hospital. Upon reevaluation, the apparently high rate for clubfoot, initially a category that pointed most convincingly to a localized problem, was attributed to reporting differences. However, this report was never published, and presumably its conclusions are moot, in view of the Burdeshaw and Shaffer report.
FINAL CRITIQUE: Based on the data presented and the

statistical treatment thereof, there is little if any evidence toward an association of abnormal incidences of congenital anomalies and exposure to RFR at the levels occurring in the vicinity of military bases using radar facilities.

REFERENCES: Peacock, P. B. , S. R. Williams, and E. Nash, RELATIONSHIP BETWEEN THE INCIDENCE OF CONGENITAL ANOMALIES AND THE USE OF RADAR IN MILITARY BASES, Final Report, Report No. III, Project No. 3118, Contract No. 68-02-0791, submitted by Southern Research Institute to EPA (Nov. 1973) (unpublished)

Peacock, P. B. , J. W. Simpson, C. A. Alford, Jr., and F. Saunders, CONGENITAL ANOMALIES IN ALABAMA, J. Med. Assoc. Ala., Vol. 41, No. 1, pp. 42-50 (1971)

Cohen, B. H., A. M. Lilienfeld, S. Kramer, and L. C. Hyman
PARENTAL FACTORS IN DOWN'S SYNDROME-RESULTS OF THE SECOND BALTIMORE CASE-CONTROL STUDY
In E. G. Hook and I. H. Porter (eds.), POPULATION GENETICS-STUDIES IN HUMANS, Academic Press, New York, pp. 301-352 (1977)
Study type: (1) Epidemiologic, (2) Mutagenic and cytogenetic; IN-VIVO; HUMAN
Effect type: Radiation-induced Down's syndrome
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Primarily to ionizing radiation for diagnostic and therapeutic purposes
REVIEWER SUMMARY: In an earlier study of Down's syndrome in Baltimore for the period from Jan 1946 through Sept 1962 (Sigler et al., 1965), data for 216 cases and 216 control children matched for hospital of birth (or at home), sex, birthdate (within 6 months), and maternal age (within 1 year) at time of birth were analyzed for statistically significant differences primarily in exposure to ionizing radiation used for diagnostic, fluoroscopic, and therapeutic purposes, but also in presumed exposure of the fathers to RFR because of military service. In the present study, the data from the earlier study, denoted as the "Original Series," were reexamined, together with the data regarding 128 additional matched pairs for 1945 and for Oct 1962 through 1968, denoted as the "Current Series." More detailed questions about RFR exposure and military service were incorporated in the Current Series questionnaires, and service record information on the fathers was acquired. An attempt was made to acquire similarly detailed data on the fathers of the Original Series. In addition, a chromosome study of the fathers was undertaken to determine whether there was any detectable residual damage in the chromosomes of the peripheral blood. After considering the more detailed exposure information, the following findings were reported for the Current Series: 15.7% of case fathers and 21.3% of control fathers had received radar exposure; combining the probably-exposed with the definitely-exposed groups, the corresponding values were 26.0% and 28.3%. The re-evaluated Original Series values for definitely-exposed fathers were 18.6% for case fathers and 15.2% for controls, and when probably-exposed fathers were added the values were 20.6% and 15.7%. When the data from the Original Series and from the Current Series were combined, the values for case vs control fathers were 17.4% vs 17.5% for definitely exposed and 22.7% vs 20.6% when "some" exposure was included. None of the foregoing comparisons showed statistically significant differences. The

results of the chromosome studies have not been reported yet. The authors concluded that the Current Series did not confirm the suggestions of the Original Series that there was either an excess of radar exposure or a larger proportion of fathers with military service prior to the conception of the cases of Down's syndrome. The authors note that "in view of the suggestive findings of the original series with regard to a possible radar association, it was certainly necessary to investigate this question further. The initial steps were taken. A replication study was the simplest and least expensive immediate approach. Supplementing it with the independent search of service records added an objective approach eliminating any possible differential in parental responses. These methods having been attempted with inconclusive findings, it is now necessary to look to the prospective, longitudinal, surveillance studies to resolve the issue."

OTHER INFORMATION: The authors remark that the statistically significant differences in medical (ionizing) radiation history between case and control mothers found in the Original Series were absent in the Current Series. They speculate that this finding may be ascribable to increased awareness by medical practitioners of the potential health hazards of ionizing radiation to women in the child bearing years, leading to more restricted exposure.

FINAL CRITIQUE: The major problem with this, as well as other retrospective epidemiologic studies for possible RFR-induced bioeffects, is the difficulty in determining differences, with any degree of confidence, in exposure levels and durations between so-called exposed groups and unexposed groups. Records and interviews regarding military service, even at stations where the use of radar and communications systems is prevalent, rarely provide insight into actual exposure histories for either group. In view of the absence of statistically significant differences between the incidence of Down's syndrome and "radar" exposure of the fathers in the Current Series and in the combination of the Current and the Original Series, the positive finding of such an association in the Original Series appears to be a statistical anomaly.

REFERENCES: Sigler, A. T., A. M. Lilienfeld, B. H. Cohen, and J. E. Westlake, RADIATION EXPOSURE IN PARENTS OF CHILDREN WITH MONGOLISM (DOWN'S SYNDROME), Bull. Johns Hopkins Hosp., Vol. 117, pp. 374-395 (1965)

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHZ RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 52-57 (1974)
Study type: (1) Epidemiologic, (5) Nervous system, (6) Behavioral, (8) Immunological, (9) Biochemical/physiological; IN-VIVO; HUMAN
Effect type: RFR-induced health changes
Frequency/wavelength: 40-200 MHz
Modulation: Not specified
Power Densities: Not given other than "non-thermal intensity"
SAR: Not given
Exposure conditions: Mostly occupational for more than 5 years, but also one laboratory investigation with human volunteers
REVIEWER SUMMARY: A group of specialists (number not given) working with RFR generators from 1 to 9 years was given complex clinical examinations. Frequent occurrence of functional changes in the central nervous system was reported. The principal form of neurodynamic disturbance was vegetative dysfunction accompanied by neurasthenic symptoms. No organic lesions were found. The authors state that the relationship between the frequency of neurodynamic disturbances and duration of work was clear-cut. Several of the manifestations were biphasic, e.g., the level of activity of thermal receptors was higher for those employed for up to 1 year than for controls, and was lower for those employed for 3 to 9 years. Among the many specific changes reported were deviations in the physiochemical and functional properties of erythrocytes and leukocytes including lower osmotic resistance of leukocytes and lower phagocytic reaction that led to weakened immunobiological reactivity. The authors also report the following: "Experimental data obtained in volunteers under laboratory conditions of irradiation mimicking industrial variants revealed certain principles concerning general physiologic responses of the human body towards electromagnetic fields. The thermoregulatory system, some systems of hemodynamics and thermal, optical and auditory analysers proved most functionally reactive and sensitive to the influence of experimental irradiation. The dynamics of functional deviations were compared with those accompanying the presumed action of the factor. The irradiation was systematic with daily 15 min exposures and the 30 days' duration of each series of treatments. The ambient temperature ranged from 22.6 to 23.4 deg C with relative humidity of 40-46%. The results showed that some functional deviations took place during irradiation, while others followed it. The skin temperature of distal parts of the body (hands, feet) was elevated during the whole period

of actual irradiation with simultaneous intensification of heat loss through emission and demobilization of heat receptors. The number of active cold receptors sharply increased."
OTHER INFORMATION: No RFR intensity values are given. Most of the findings are presented in narrative form, and no actual data are cited. Bar graphs depicting changes, relative to controls, of a few specific parameters with exposure duration are given, but the nature of the control group is not described and no statistical treatment is presented.
FINAL CRITIQUE: Because of the lack of quantitative data on RFR intensities and on any of the effects relative to an unspecified control group, this paper provides little if any useful information to affirm or deny the occurrence of possible adverse effects of occupational exposure to RFR.
REFERENCES: None

Klimkova-Deutschova, E.
NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 268-272 (1974)
Study type: (1) Epidemiologic, (5) Nervous system, (6) Behavioral, (9) Biochemical/physiological; IN-VIVO; HUMAN
Effect type: Subjective complaints, subclinical and clinical manifestations
Frequency/wavelength: Various in range 0.45 MHz-30 GHz
Modulation: Various
Power Densities: Up to 400 V/m (40 mW/cm.2 equiv.) Av
SAR: Unspecified
Exposure conditions: Various occupational situations
REVIEWER SUMMARY: From a total of 530 persons in various industrial situations, a sample of 352 workers was selected and analyzed by computer on the basis of 119 parameters, and divided into the following groups:
1. Workers engaged in metal welding, exposed to frequencies ranging from 0.5 MHz up to 3.5-32 MHz.
2. Workers from two steel factories engaged in tempering steel and exposed to frequencies of 0.45-150 MHz, with a daily exposure of 50-112 V/m, and occasionally 400 V/m.
3. Welders of plastics: frequency range 12-150 MHz, daily exposure 20-57.7 V/m.
4. Technicians operating television transmitters.
5. Workers at a radio transmitting station operating at a wide range of frequencies, from 6 MHz up to 30 MHz, and using a pulsed field system.
6. Persons exposed to radiation in the 3-13 cm waveband working in industry and at research institutes with frequencies ranging from 3 GHz to 30 GHz. Intensity measurements showed permissible levels in some places, but in others values exceeding the permissible level ten or more times were found.
7. Persons working on a linear particle accelerator.
8. A mixed group which included the administrative staffs of two factories, who were not directly exposed to nonionizing radiation, some workers with exposures of less than 300 MHz and others with exposures of 300-800 MHz.
Among the general conclusions cited were:
(1) Confirmation that disturbances of the nervous system may be divided into three main stages:
(a) The neurasthenic syndrome with autonomic disorders,
(b) Pseudoneurasthenia with similar subjective complaints, but with microsymptoms of an organic nature, especially in motor systems,
(c) Very rare cases of encephalopathy.
(2) The occurrence of contralateral responses to cerebellar and extrapyramidal disturbances facilitates the detection of early

signs of extrapyramidal syndromes, which are identical with those caused by cerebellar irritation.
(3) The predominance of fatigue in certain of the exposed groups was paralleled by a reduction in vigilance, as noted in the EEG recordings and in earlier studies of higher nervous functions.
(4) The occurrence of synchronized EEG activity, with slow rhythms of high amplitude similar to those seen in epileptic seizures, taken in conjunction with the clinical and biochemical findings, permits the conclusion that the involvement of the nervous system is localized in the mesodiencephalic region. Such activity is seen in persons subjected to high levels of exposure, particularly in the form of a pulsed field.
(5) Possible explanations of the pathophysiology include direct penetration of the radiation into the midline structures and the thermal effect in the cisterna magna, which would explain the rare cases of arachnitis of the posterior fossae and the cerebellar phenomena. The rectangular branching of the blood vessels of the temporal and basal ganglia explains the slowing of the blood stream in these parts of the brain, accompanied by reduced oxygenation. It may be assumed that the subclinical paroxysmal activity is induced by alkalosis resulting from these disturbances.
(6) The nonthermal effects and reversible neurotic manifestations may be attributed to the interruption of synaptic transmission and to changes in reflex activity under enzymatic influences.
Specific findings included electroencephalographic disorders (consisting of synchronized waves of high amplitude and slow rhythm) and biochemical changes (such as elevation of fasting blood glucose, serum beta-lipoprotein, and cholesterol). Changes in brain-wave patterns and in blood sugar, protein, and cholesterol levels were described as more pronounced in the people exposed in the 3-30 GHz range.
OTHER INFORMATION: The author points out that "...when the investigations were started preventive measures were not strictly observed and less attention was paid to the hazards than is the case today. Nowadays, strict hygienic supervision of working places prevents the development of serious organic injury. Our previous results provide useful evidence of the nature of the lesions that can develop."
FINAL CRITIQUE: The field intensities cited correspond to the free-space-equivalent power density range of about 0.1 to 40 mW/cm.2, which overlaps the range for which Western investigators have reported positive findings in animal studies (but not necessarily the specific effects mentioned by this author). The author states that differences among groups for specific manifestations were either statistically significant

at the 0.05 level, or at the 0.01 level, or not statistically significant. However, numerical results and the statistical treatment thereof are not presented, thereby rendering comparisons with the results of others impossible. Nevertheless, because symptomatology similar to the "neurasthenic syndrome" has not been reported in Western studies, it is difficult to accept such findings by this and other Eastern European investigators (e.g., Sadchikova, 1974) at face value.

REFERENCES: Sadchikova, M. N., CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS, in P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974).

Lilienfeld, A. M., J. Tonascia, S. Tonascia, C. H. Libauer, G. M. Cauthen, J. A. Markowitz, and S. Weida
FOREIGN SERVICE HEALTH STATUS STUDY: EVALUATION OF HEALTH STATUS OF FOREIGN SERVICE AND OTHER EMPLOYEES FROM SELECTED EASTERN EUROPEAN POSTS .
Final Report, July 31, 1978, Contract No. 6025-619073, Dept. of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, MD (1978)
Study type: (1) Epidemiologic, (8) Immunological, (9) Biochemical/physiological; IN-VIVO; HUMAN
Effect type: Possible RFR-induced mortality and morbidity
Frequency/wavelength: 0.5 to 10 GHz; max. in 2-3 GHz
Modulation: Up to 7 noise bands, each a few MHz wide
Power Densities: Up to 18 microwatts/cm.2 Av
SAR: Unknown
Exposure conditions: Intermittent
REVIEWER SUMMARY: The U.S. Embassy in Moscow has been subjected to RFR since 1953, the year after the U.S. moved its chancery to Checkovsky Street. Prior to 1963, the presence of RFR was detected intermittently during routine surveillances of the building, at which time continuous monitoring of the signals was instituted. The signals consisted of up to 7 noise bands, each a few MHz wide, in the frequency range from 0.5 to 10 GHz, with maximum amplitudes in the 2-3 GHz range. The maximum incident average power densities and exposure durations varied with the period: 5 microwatts/cm.2 for 9 hours/day from 1953; 15 microwatts/cm.2 for 18 hours/day from June 1975 to February 7, 1976; and less than 1 microwatt/cm.2 for 18 hours/day thereafter. The highest average power density reported was 18 microwatts/cm.2 in one part of the southeast corner of the building, where beams from two sources converged. In this study, the health of U.S. personnel assigned to the Moscow embassy from 1953 to 1976 was compared with the health of those assigned to other Eastern European embassies. Totals of 1,827 employees and 1,228 dependents were identified as having been at the Moscow embassy during the period. The control population consisted of 2,561 employees and 2,072 dependents assigned to embassies and consulates in Budapest, Leningrad, Prague, Warsaw, Belgrade, Bucharest, Sofia and Zagreb during the same time period. Periodic tests for RFR at the control sites showed only background levels. Medical reports were reviewed for 1,209 Moscow employees and 834 dependents. The corresponding numbers for the control group were 1,882 and 1,507. Health questionnaires were returned by 969 Moscow employees and 1,129 control employees. There were no discernible differences between the Moscow and control groups in total mortality or mortality from specific causes, nor were there differences in mortality between the Moscow and control groups of dependent children or adults. With the

exception of cancer-related deaths among female employee groups (both Moscow and control), mortality rates for both Moscow and control groups were less than for the U.S. population at large. Although the study groups were subject to a large variety of health problems, on the basis of the medical records these problems were shared nearly equally by both Moscow and control groups with two exceptions: the Moscow male employees had a threefold higher risk of acquiring protozoal infections, and both men and women of the Moscow group were found to have slightly higher frequencies of most of the common kinds of health conditions reported. However, the authors could not relate these two exceptions to RFR exposure. From the health questionnaire information, the authors reported that there were some excesses in the Moscow employee groups as compared with the controls: more correctable refractive eye problems, more psoriasis in men and anemia in women, and more frequent cases of depression, irritability, difficulty in concentrating, and memory loss. However, the authors noted that "In view of the possibilities which had been publicized of the increased danger to their health and that of their children, it is not at all surprising that the Moscow group might have had an increase in symptoms such as those reported. However, no relationship was found between the occurrence of these symptoms and exposure to microwaves; in fact, the four symptoms mentioned earlier, which showed the strongest differences between the Moscow and Comparison groups, were all found to have occurred most frequently in the group with the least exposure to microwaves." For dependents, the authors found no differences between the adult Moscow and control groups. Moscow dependent children had twice as high a frequency of mumps as the control children. The incidence of congenital anomalies occurring in children born after arrival of the parents at the duty station was comparable for the Moscow and control groups. Finally, the authors summarized as follows: "With very few exceptions, an exhaustive comparison of the health status of the State and non-State Department employees who had served in Moscow with those who had served in other Eastern European posts during the same period of time revealed no differences in health status as indicated by their mortality experience and a variety of morbidity measures. No convincing evidence was discovered that would directly implicate the exposure to microwave radiation experienced by the employees at the Moscow embassy in the causation of any adverse health effects as of the time of this analysis."

OTHER INFORMATION: The authors of this study recognized and commented on the limitations placed on the study by their inability to acquire complete sets of medical records, death certificates, and returned health questionnaires, and by the imprecision of the classification of the individual employees

according to probable extent of RFR exposure. Furthermore, they noted that the highest exposure levels were recorded late in the study and therefore, for the subgroup with the highest exposure, the period of time during which health effects might become apparent was the shortest. They also noted that the size of the study population was insufficient to detect excess risks that were less than twofold for many of the medical conditions studies. Pollack (1979) briefly summarized the exposure conditions and the results of this study. Brief discussions of this study are also in the review papers by Silverman (1979, 1980).

FINAL CRITIQUE: Despite the limitations of the study acknowledged by the investigators, their findings of no RFR-related increases in mortality or morbidity appear valid. It should be noted that the 18 microwatts/cm.2 maximum level cited was applicable to one part of the embassy and only if a person had been at a window unclothed, so that the exposure levels for most of the personnel for most of the time were probably well below the maximum permissible level (5 microwatts/cm.2) specified in the USSR standard of general population exposure.

REFERENCES: Pollack, H., EPIDEMIOLOGIC DATA ON AMERICAN PERSONNEL IN THE MOSCOW EMBASSY, Bull. N. Y. Acad. Med., Vol. 55, No. 11, pp. 1182-1186 (1979)
0018-9219/80/0100-0078 Silverman, C., EPIDEMIOLOGIC STUDIES OF MICROWAVE EFFECTS, Proc. IEEE, Vol. 68, No. 1, pp. 78-84 (1980)
Silverman, C., EPIDEMIOLOGIC APPROACH TO THE STUDY OF MICROWAVE EFFECTS, Bull. N.Y. Acad. Med., Vol. 55, No. 11, pp. 1166-1181 (1979)

Pazderova, J.
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)
Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, pp. 265-271 (1971). English translation: JPRS No. UDC 616-001.228.1-057-07 (1971)
Study type: (1) Epidemiologic, (4) Ocular; (5) Nervous system, (6) Behavioral, (9) Biochemical/physiological, IN-VIVO; HUMAN
Effect type: RFR induced effects on health
Frequency/wavelength: 48.5 to 230 MHz
Modulation: Video
Power Densities: 0 to 9.2 V/m mean (2.1 microwatt/cm.2 equiv.)
SAR: Unknown
Exposure conditions: Occupational at TV stations in Czechoslovakia
AUTHOR SUMMARY: Fifty-eight employees of television transmitter stations, 49 males and 9 females, were examined. Their mean age was 32.1 years, and their mean length of employment at television transmitters was 7.2 years. The transmission band ranges from 48.5 to 230 MHz. The electromagnetic field's mean intensity was 2.9 V/m (s = 0.4, range from 0 to 9.2 V/m). The mean exposure per workday, computed as the product of the field intensity (V/m) and of the period of exposure (hours), was 30.7 (s = 3.8, range from 6.5 to 97.1). The error in the methods of measurement is given as 30 percent. The subjects' state of health was evaluated on the basis of a complete medical checkup that included the patients' history and the following tests: ECG, x-rays of heart and lungs, erythrocyte sedimentation rate, urinalysis, liver tests, and gynecological examination of the female subjects. The following examination and test results were compared with control groups and were tested for statistical significance: blood pressure; complete blood count including thrombocytes, protein spectrum and blood-sugar level; and ophthalmological, neurological, psychiatric and psychological examinations. Interpretations of the electroencephalograms will be published separately. In the examined subjects we found no sign of damage due to electromagnetic radiation. Among the laboratory test results, the mean plasma protein levels were significantly increased. Even though we do not regard this as pathological, the possibility of its correlation with exposure to electromagnetic radiation cannot be ruled out. The other test results did not differ from those of the control groups.
OTHER INFORMATION: The 58 subjects monitored the operation of the transmitters during most of their working shifts and they recorded readings and performed adjustments and maintenance on the transmitters during the remainders of their shifts. The shifts were of varying length but averaged 40 hours per week.

[illegible] and laboratory data from the subjects were [illegible] compared with data taken from the literature for [illegible] Czechoslovakian persons in the same age group, i.e., no [illegible] group was selected and examined. Specific tests included: pulse rate; blood pressure; blood-protein spectrum [illegible] percentages of total protein; alpha-1, alpha-2, beta, and gamma globulins; and albumin-globulin ratio); erythrocyte, leucocyte, and platelet counts; liver tests; chest x-rays; [illegible]; and gynecological examinations of the 8 females. [illegible] subjects were examined for neurovegetative symptoms [illegible], and 46 subjects underwent psychiatric [illegible] and completed questionnaires aimed toward detecting [illegible] symptoms. Ocular examinations were also [illegible].

[illegible]: The only statistically significant finding was [illegible] plasma protein levels were higher than "normal" [illegible] literature, a finding that even the [illegible] investigators [illegible] the appropriateness of the use of [illegible] values is highly questionable, and the [illegible] the desirability of a control group matched for [illegible] and educational background." See also the [illegible] by Marhasova et al. (Pazderova et al., 1974).

[illegible] Marhasova, J., J. Pickova, and V. Bryndova, BLOOD [illegible] IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING [illegible] in: Czerski et al., (eds.), BIOLOGIC EFFECTS AND [illegible] OF MICROWAVE RADIATION, Polish Medical [illegible], pp. 281-288 (1974)

Pazderova, J., J. Pickova, and V. Bryndova
BLOOD PROTEINS IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING STATIONS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 281-288 (1974)
Study type: (1) Epidemiologic, (9) Biochemical/physiological; IN-VIVO; HUMAN
Effect type: RFR-induced blood-chemistry changes
Frequency/wavelength: 640-1500 kHz; 3-30 MHz; 60-300 MHz
Modulation: Video and/or audio
Power Densities: For 60-300 MHz: up to 10 V/m; for other bands: up to 65 V/m
SAR: Unknown
Exposure conditions: Occupational at TV, shortwave, and standard AM radio broadcast stations in Czechoslovakia
REVIEWER SUMMARY: Results of a prior investigation of the effects of occupational exposure to TV transmitters in Czechoslovakia (Pazderova, 1971) had indicated no changes in health status except for modifications of the blood protein ratios (e.g., gamma-globulin percentages). The present paper describes results of repeating the investigation. In the 60-300 MHz (TV) range, 51 people were exposed to fields ranging from about 0.5 to 9 V/m (the latter corresponding to about 0.02 mW/cm.2 free-space equivalent power density). The mean age of the group was 35.2 years and their average exposure duration was 10.4 years. In the 3-30 MHz ("SW") range, 19 people with a mean age of 39.3 years were exposed for an average of 16.8 years to about 66 V/m (about 1 mW/cm.2 equiv.), and in the 640-1500 kHz ("MW") range, 39 people with a mean age of 41.3 years were exposed for 16.8 years to about 55 V/m (0.8 mW/cm.2 equiv.). A group of 59 workers (35.4 years mean age) served as controls. The authors indicate that the only difference between exposed and control groups was that those included in the exposed groups had worked in irregular shifts whereas more than half of the control people only worked morning shifts. The results showed that the levels of blood proteins and their fractions were within physiologic limits, both mean values and individual ones, but statistically significant differences were found between the mean values for the control and exposed groups. Total blood proteins were significantly higher (to the 0.05 level) for the MW group than the control; the alpha-one globulin values for the MW and SW groups were significantly higher (to the 0.01 level) for all three exposed groups relative to controls, with the greatest elevation for the SW group. The differences for alpha-two globulins were not significant, but the gamma-globulin level was depressed for the TV group and elevated for the MW group. The authors then state:

[illegible] findings confirmed the data from the literature on the existence of blood protein changes in persons and experimental animals exposed to electromagnetic radiation. To our great surprise, the character of the changes diverged from those so far described, as we did not find any elevation of gammaglobulin, which is considered to be typical. We are unable to explain this difference, unless we attribute it to the fact that, contrary to our previous investigation, blood samples were taken directly at the transmitting stations immediately after exposure to electromagnetic fields. This explanation [illegible] remains open to discussion. The more pronounced changes in our examinations might be ascribed to the higher and longer exposures in comparison with TV technicians."

[illegible] INFORMATION: None

[illegible] COMMENTS: The absence of a control group that received [illegible] no RFR exposure renders questionable finding of [illegible] differences attributable to RFR exposure. Moreover, although statistically significant differences in blood protein levels were reported, the values did not exceed normal physiologic limits. In short, this study does not provide any evidence that chronic exposure to the RFR frequencies and intensities cited had any discernible effects on those exposed. It is likely that the reported changes in blood protein levels were due to other factors.

ABSTRACTED BY: Pazderova, J., WORKERS' STATE OF HEALTH UNDER [illegible] EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND [illegible] MHz), Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, [illegible] 225-231 (1971). English translation: JPRS No. UDC [illegible] 578.1:03:[illegible] 62 (1971)

Peacock, P. B., J. W. Simpson, C. A. Alford, Jr., and E. Sanders
CONGENITAL ANOMALIES IN ALABAMA
J. Med. Assoc. Ala., Vol. 41, No. 1, pp. 42-50 (1971)
Study type: (1) Epidemiologic, (3) Teratogenic and developmental abnormalities; IN-VIVO; HUMAN
Effect type: RFR-induced congenital anomalies among white and black populations
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Unknown
REVIEWER SUMMARY: In Alabama, a statewide file by counties is kept of all birth defects reported each month. The information is stored in a computer in the School of Public Health, University of Alabama School of Medicine, and is available for statistical analysis. In this paper, data for the period from July 1969 to November 1970 are analyzed. The overall rate of 10.3 newborns with anomalies per 1,000 births is comparable with rates elsewhere. However, the white rate of 11.1 was higher than the non-white rate of 9.7. There was an excess of polydactyly among the black infants (125 cases versus 36 cases among the white infants), and the authors indicate that if this type of anomaly is excluded, the overall rates would be 10.5 for whites versus only 5.5 for blacks. If each anomaly is assumed to be randomly distributed, then 6 of the 67 counties (Butler, Calhoun, Coffee, Dale, Henry, and Jefferson) had statistically significant (p less than 0.05) excesses for one or two specific anomalies. In particular, Coffee and Dale counties (in which Fort Rucker is located), had higher rates for clubfoot than the white infants, and Dale also had a higher rate for cleft palate. In Calhoun, the incidence of anencephaly was twice that for white babies, whereas that of cleft palate and [illegible] was twice as for black infants. Butler and Henry counties had excesses of spina bifida for whites, and Jefferson had an excess of genital anomalies for whites.
OTHER INFORMATION: In this paper, the authors make no mention of Fort Rucker, or of possible causal factors for the excess incidences cited. They also mention overall rates found by other investigators for other regions within and outside of the U.S. They cite rates ranging from 7.4 to 75.4 per 1,000, depending on the population studied, the types of anomalies included, whether the investigators personally examined all births or relied on a notification system, and on whether the children concerned were followed prospectively for some years.
FINAL CRITIQUE: In a subsequent unpublished report (Peacock et al., 1973), the data in this paper plus additional data were analyzed, thus rendering the findings of this paper moot. In a

[illegible] paper by Burdeshaw and Schaffer (1977), the same data are treated with different statistical methods than those used by Peacock and coworkers, and different conclusions are given.

REFERENCES: Burdeshaw, J. A. and S. Schaffer, FACTORS ASSOCIATED WITH THE INCIDENCE OF CONGENITAL ANOMALIES: A LOCALIZED INVESTIGATION, Final Report, Report No. XXIII, May 24, 1973-March 31, 1976, EPA-600/1-77-016, Contract No. 68-02-0791 (March 1977)

Peacock, P. B., S. R. Williams, and E. Nash, RELATIONSHIP BETWEEN THE INCIDENCE OF CONGENITAL ANOMALIES AND THE USE OF PESTICIDES IN MILITARY BASES, Final Report, Report No. III, Project No. [illegible], Contract No. 68-02-0791 submitted by Southern Research Institute to EPA (Nov. 1973) (unpublished)

Robinette, C. D. and C. Silverman
CAUSES OF DEATH FOLLOWING OCCUPATIONAL EXPOSURE TO MICROWAVE RADIATION (RADAR) 1950-1974
In D. G. Hazzard (Ed.), SYMPOSIUM ON BIOLOGICAL EFFECTS AND MEASUREMENT OF RADIOFREQUENCY/MICROWAVES, Dept. of Health, Education, and Welfare, Washington, D.C., HEW Publication No. (FDA) 77-8026 (1977)
Study type: (1) Epidemiologic; (9) Biochemical/physiological; IN-VIVO; HUMAN
Effect type: Mortality, morbidity
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Occupational exposure to various radar systems
REVIEWER SUMMARY: In this study of personnel who had served in the Navy during the Korean War, a group of approximately 20,000 persons was selected and classified as having had occupational exposure to RFR on the basis of their titles of Electronics Technician, Fire Control Technician, or Aircraft Electronics Technician; another group of about 21,000 persons was classified as not having had occupational exposure because of their titles of Radioman, Radarman, or Aircraft Technicians Mate. For brevity, the latter group was referred to as the control group, even though these personnel may have had some RFR exposure--presumably much less than the first group. The study utilized only extant records, covering 1955 to 1976, of mortality and morbidity (both in service and later in Veterans Administration hospitals), and of both granted and disallowed requests for disability compensation. Only mortality results are presented in this paper, which show 619 deaths from all causes for the occupationally exposed group versus 579 deaths for the control group, with the difference being not statistically significant. It was noted that these death rates for both groups were lower than those for the comparable age group in the U.S. population at large. Examination of these decedent data in more detail showed a significantly higher death rate from trauma in the exposed group; however, many of the trauma-associated deaths resulted from military aircraft accidents, and a higher proportion of the exposed group had subsequently become flyers. The incidence of deaths associated with arteriosclerotic heart disease was significantly lower in the exposed group. No significant differences were noted between the two groups in terms of total mortality or in terms of mortality from any of about 20 assigned categories of causes of death.
OTHER INFORMATION: In a subsequent paper, Silverman (1979) reviews a number of epidemiological studies of possible

RFR-induced effects, including this study of Navy personnel. Again, details regarding morbidity and other health-related aspects are not furnished, but she does state: "Differential health risks associated with potential occupational exposure to radar in the Navy more than 20 years ago are not apparent with respect to long-term mortality patterns or hospitalized illness around the period of exposure, two endpoints for which there is virtually complete information for the total study group. Later hospitalization (in Veterans Administration facilities only) and awards for service-connected disability, the two other endpoints examined, provide incomplete information. While some significant differences among the occupational groups classified by level of potential exposure have been found with respect to all endpoints studied, the differences could not be interpreted as a direct result of microwave exposure." She also points out the possibility that effects involving the cardiovascular, endocrine, and central nervous systems may be transient and may disappear shortly after termination of exposure or not produce symptoms that warrant hospitalization. In a still later review paper (Silverman, 1980), she provides much the same information contained in Silverman, 1979.

FINAL CRITIQUE: The two groups compared in this study can be characterized as a high-exposure and a low-exposure group. Comparisons of these two groups with an unexposed group would have strengthened the study. The authors mention that they had devised a Radar Exposure Index for the occupationally exposed group, but give no data. In Silverman (1979), presumably the same index is called the Exposure Hazard Number, defined as the sum of the power ratings of all gunfire-control radars aboard the ship or search radars aboard the aircraft to which the technician was assigned, multiplied by the number of months of assignment. The distribution by Exposure Hazard Number of personnel among the three occupations comprising the high-exposure group indicates that the Fire Control Technician and the Aviation Electronics Technician categories had much larger percentages of individuals with high values of Exposure Hazard Number than the Electronics Technician category, but the investigators present no comparisons of mortality data among these three categories. It should also be noted that no comparisons between the high-exposure and low-exposure groups of morbidity data are given. Despite these shortcomings, the results of this study show no evidence for RFR-induced increases in mortality for the high-exposure group.

REFERENCES: 0018-9219/80/0100-0078 Silverman, C , EPIDEMIOLOGIC STUDIES OF MICROWAVE EFFECTS, Proc. IEEE, Oct. 68, No. 1, pp. 78-84 (1980)

Silverman, C., EPIDEMIOLOGIC APPROACH TO THE STUDY OF MICROWAVE EFFECTS, Bull. N.Y. Acad. Med., Vol. 55, No. 11, pp. 1166-1189 (1979)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974)
Study type: (1) Epidemiologic, (4) Ocular, (5) Nervous system, (6) Behavioral, (7) Endocrinological, (9) Biochemical/physiological, (14) Review; IN-VIVO; HUMAN
Effect type: Behavioral and clinical manifestations of "microwave sickness"
Frequency/wavelength: Microwaves (unspecified)
Modulation: Unspecified
Power Densities: A few mW/cm.2
SAR: Unspecified
Exposure conditions: Occupational tuning and testing of diverse equipment for up to 15 years
PAPER SUMMARY: Clinical observations are presented on the health status in two groups of workers engaged in the regulation, tuning and testing of diverse radio-equipment emitting radiation in the microwave range. Both groups were comparable with respect to sex and age, but differed in intensity of exposure and duration of work. Young men with a long (5-15 years) history of employment with microwave sources predominated in both groups. Those in the first group (1000) were subject to the influence of a power density of up to a few mW/cm.2. The second group (180) comprised people exposed to microwaves at lower intensities, which as a rule did not exceed several hundredths of a mW/cm.2. More significant exposure could have taken place during extremely short periods. Some nervous tension during work could not be excluded. A group of people (200), matched with respect to sex, age and character of work processes which did not involve exposure to microwaves, served as a control. Of 16 kinds of symptoms reported, the incidences were higher for the higher-power-density group in seven cases, higher for the lower-power-density group in nine cases, and essentially equal in two cases. Values of symptoms for the control group were less than those for at least one of the two exposure groups in all 16 cases. Symptoms reported included fatigue, irritability, sleepiness, partial loss of memory, bradycardia, hypertension, hypotension, cardiac pain, and systolic murmur. Eye examinations revealed opacities, mainly in the cortical layer. The numbers of opacities for the exposure groups did not exceed control values. A few subjects in the first group who worked under unspecified "unfavorable conditions" developed cataracts. Based on prior work as well as that discussed in the paper, the "asthenic syndrome" is considered. A table in the paper describes 100 cases of "microwave sickness," and the text predicts little chance

for recover, unless the patient is removed from the work environment.

OTHER INFORMATION: None

FINAL CRITIQUE: Although figures are included that show percentages of changes in the 16 symptoms for the two exposure groups and the control group (and standard error bars), statistical treatments of the data are not provided. Consequently, whether any of the reported differences among the three groups is statistically significant cannot be determined. Also, symptomatology similar to the "asthenic syndrome" or "microwave sickness" has not been reported in Western studies, so it is difficult to accept these USSR findings at face value. In the light of the extensive research on RFR-induced ocular damage, the incidence of cataracts in a few workers working under "unfavorable conditions" must be interpreted as an indication of exposure to power densities well in excess of the threshold. It is also interesting to note that even though the occupational standard for exposure to RFR in the USSR is 10 microwatts/cm.2 (Stuchly and Repacholi, 1978), the investigator was able to locate 1,000 people who were exposed to values well in excess of this standard for long periods of time.

REFERENCES: Stuchly, M. A. and M. H. Repacholi, MICROWAVE AND RADIOFREQUENCY PROTECTION STANDARDS, in Trans. International Microwave Power Institute: MICROWAVE BIOEFFECTS AND RADIATION SAFETY, Vol. 8, pp. 95-101 (1978)

[illegible], M.
[illegible] HEALTH STATE OF MICROWAVE WORKERS
[illegible] et al. (eds.), BIOLOGIC EFFECTS AND HEALTH
HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers,
Warsaw, pp. 276-280 (1974)

[illegible] (1) Epidemiologic, (4) Ocular, (5) Nervous system,
[illegible] Biophysical/physiological; IN-VIVO; HUMAN
Effect type: Lens changes, abnormal EEG and ECG,
gastrointestinal complaints
Frequency/wavelength: Unspecified radar frequencies
Modulation: Pulsed
Power Densities: Greater than and less than 0.2 mW/cm.2 Av
Site: Unknown
Exposure conditions: Occupational
ABSTRACT SUMMARY: The health status and fitness for work of a
group of 841 men of ages ranging from 20 to 45 years was
investigated. Of these persons, 507 were occupationally exposed
to microwave EMR (of unspecified characteristics "within the whole
range used in radar operations") during working hours at power
densities (presumably average) exceeding 0.2 mW/cm.2 for 2 to
[illegible] years (Group I). The other 334 persons (Group II) were
exposed to less than 0.2 mW/cm.2. This group was used for
comparison with Group I because of the difficulties in
selecting an adequate unexposed group working under otherwise
similar or closely controlled conditions. In both groups hygienic
conditions were comparable, i.e., the type and intensity of
nervous stress factors, changes in circadian cycle, noise
[illegible] temperature and humidity of the rooms, etc.
[illegible] included detailed ophthalmoscopic examination
[illegible] slit-lamp and a neurologic check-up,
[illegible], psychologic tests and EEG recordings. Each
[illegible] was rated for: (1) fitness for work, with the
[illegible] of unfit because of ophthalmic
[illegible], other disorders, (2) frequency of functional
[illegible], sideroses of the eye, neuroses, gastrointestinal,
[illegible], EEG, and (3) lens translucency, subclassified as 1,
[illegible]. Statistical comparisons of the two groups for
[illegible] were done by age and by duration of
[illegible]. No statistically significant differences (at the
[illegible] level) between the two groups were found. However, within
each group, there was a correlation between lens translucency
and age was found. Also, correlation was found between lens
translucency and age for Group I but not Group II. Additional
regression analysis indicated a high degree of correlation
between [illegible] and duration of employment.
[illegible] INFORMATION: None
[illegible] ADDITIONAL: No information was given regarding possible
[illegible] of either pulsed or average power density to which
[illegible] I were exposed. The author does indicate that

the individuals "worked both in closed rooms and in the open, observing typical individual protective measures according to the regulations of work safety and hygiene existing in this country." However, there is no mention of adherence to the then prevailing occupational RFR exposure standards, which were the same as those of the USSR until 1972 (Stuchly and Repacholi, 1978). In fact, the value 0.2 mW/cm.2 exceeds the maximum permissible levels for a working day, indicating the likelihood of non-adherence to that standard. If indeed many of the individuals in Group I were chronically exposed to 1 or 2 orders of magnitude larger than that value, then the negative findings of this investigation would be an important contribution. The lack of more definitive exposure data vitiates but does not negate the findings.

REFERENCES: Stuchly, M. A. and M. H. Repacholi, MICROWAVE AND RADIOFREQUENCY PROTECTION STANDARDS, in Trans. International Microwave Power Institute: MICROWAVE BIOEFFECTS AND RADIATION SAFETY, Vol. 8, pp. 95-101 (1978)

[illegible], A. T., A. M. [illegible]enfeld, B. H. Cohen, and
[illegible]. S. Westlake
RADIATION EXPOSURE IN PARENTS OF CHILDREN WITH MONGOLISM
(DOWN'S SYNDROME)
Bull. Johns Hopkins Hosp., Vol. 117, pp. 374-395 (1965)
Study type: (1) Epidemiologic, (2) Mutagenic and cytogenetic;
IN-VIVO; HUMAN
Effect type: Radiation-induced Down's Syndrome
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Primarily to ionizing radiation for
[illegible] and therapeutic purposes
ABSTRACT SUMMARY: As part of an epidemiologic study in Baltimore
[illegible], the [illegible]ation of parents of both Mongoloid and control
[illegible] was evaluated for exposure to various types of
[illegible] radiation. Utilizing interview technique and medical
[illegible], the study demonstrated a statistical
[illegible] between maternal radiation exposure and Mongolism.
[illegible] of the Mongoloid children were found to have a
[illegible] history of [illegible]ed exposure to both fluoroscopic and
[illegible] radiation prior to the birth of the index child.
[illegible], there were no significant differences in ionizing
[illegible] exposure found in the fathers of the Mongol and
[illegible] children. However, a surprising increase in radar
[illegible] was discovered in a significant number of fathers of
[illegible] cases. These results suggest that maternal ionizing
[illegible] exposure may be one etiological factor responsible
[illegible] Mongolism. It is emphasized, however, that
[illegible] may be only one of several important factors
[illegible] the condition.
[illegible] METHODOLOGY: All of the 216 case children included were
[illegible] with 216 control children for hospital of birth (or at
[illegible], [illegible] date of birth (within 6 months), and nearly all
[illegible] for maternal age (within 1 year) at time of birth.
[illegible] was included only if, by personal inspection, the
[illegible] appeared to be mentally retarded and exhibited at least 6
[illegible] criteria for Mongolism, or if at least 7 such
[illegible] [illegible] on the child's medical record by a
[illegible]. The parents of the case and control
[illegible] were so well matched with regard to birthplace,
[illegible] for hospital treatment in Baltimore. Among the
[illegible] findings was that 17.7% of the case mothers had one
[illegible] more fluoroscopic examinations prior to the birth of the
[illegible] as compared with only 8.1% of the control mothers (p
[illegible]). Also, 14.5% of the case mothers reported
[illegible] radiation exposures (mostly for skin ailments)
[illegible] of the control mothers (p less than 0.01)

and 7.9% of the case mothers worked in a professional or technical capacity in medical fields versus 3.3% of the control mothers (p less than 0.05). Regarding the fathers, 63.1% of the case fathers and 56.6% of the control fathers had been in the military (the difference was not statistically significant), but 8.7% of the case fathers had reported close association with radars as technicians or operators (both within and outside military service) versus only 3.3% of the control fathers (p about 0.02). The authors concluded that "the only truly puzzling association is the suggested relationship between Mongolism and paternal radar exposure", and that "one can only speculate concerning possible mechanisms, but the association between Mongolism and radar exposure deserves further investigation."

FINAL CRITIQUE: The results of this study are reviewed primarily for historical background because they were supplanted by the results of a later, more extensive study by Cohen et al. (1977)

REFERENCES: Cohen, B. H., A. M. Lilienfeld, S. Kramer, and L. C. Hyman, PARENTAL FACTORS IN DOWN'S SYNDROME--RESULTS OF THE SECOND BALTIMORE CASE-CONTROL STUDY, in E. G. Hook and I. H. Porter (eds.), POPULATION GENETICS-STUDIES IN HUMANS, Academic Press, New York, pp. 301-352 (1977)

(2) MUTAGENIC AND CYTOGENETIC

List of Analyses

Blackman, C. F., M. C. Surles, and S. G. Benane
THE EFFECT OF MICROWAVE EXPOSURE OF BACTERIA: MUTATION INDUCTION
In C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U. S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010, pp. 406-413 (1976)

Cohen, B. H., A. M. Lilienfeld, S. Kramer, and L. C. Hyman
PARENTAL FACTORS IN DOWN'S SYNDROME-RESULTS OF THE SECOND BALTIMORE CASE-CONTROL STUDY
In E. G. Hook and I. H. Porter (eds.), POPULATION GENETICS-STUDIES IN HUMANS, Academic Press, New York, pp. 301-352 (1977) (See "Epidemiologic" for analysis.)

Dutta, S. K., W. H. Nelson, C. F. Blackman, and D. J. Brusick
LACK OF MICROBIAL GENETIC RESPONSE TO 2.45-GHz CW AND 8.5- TO 9.6-GHz PULSED MICROWAVES
0022-2739/79/0009-0275, J. Microwave Power, Vol. 14, No. 3, pp. 275-280 (1979)

Hamnerius, Y., H. Olofsson, A. Rasmuson, and B. Rasmuson
A NEGATIVE TEST FOR MUTAGENIC ACTION OF MICROWAVE RADIATION IN DROSOPHILA MELANOGASTER
0165-1218/79/0011-0217, Mutation Res., Vol. 68, No. 2, pp. 217-223 (1979)

Ray, T. ., E. C. Beyer, and C. F. Reichelderfer
MICROWAVE EFFECTS ON REPRODUCTIVE CAPACITY AND GENETIC TRANSMISSION IN DROSOPHILA MELANOGASTER
J. Microwave Power, Vol. 7, No. 2, pp. 75-82 (1972)

Sigler, A. T. , A. M. Lilienfeld, B. H. Cohen, and J. E. Whitlake
RADIATION EXPOSURE IN PARENTS OF CHILDREN WITH MONGOLISM (DOWN'S SYNDROME)
Bull. Johns Hopkins Hosp., Vol. 117, pp. 374-395 (1965) (See "Epidemiologic" for analysis.)

(2) MUTAGENIC AND CYTOGENETIC

List of Analyses (continued)

Varma, M. M., and E. A. Traboulay, Jr.
EVALUATION OF DOMINANT LETHAL TEST AND DNA STUDIES IN MEASURING MUTAGENICITY CAUSED BY NON-IONIZING RADIATION
In C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010, pp. 386-396 (1976)

Varma, M. M., E. L. Dage, and S. R. Joshi
MUTAGENICITY INDUCED BY NON-IONIZING RADIATION IN SWISS MALE MICE
In C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010, pp. 397-405 (1976)

Analyses under

(2) MUTAGENIC AND CYTOGENETIC

Blackman, C. F., M. C. Surles, and S. G. Benane
THE EFFECT OF MICROWAVE EXPOSURE OF BACTERIA: MUTATION
INDUCTION
In: C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010, pp. 408-413 (1976)

Cited figure: 1 Mutagenic and cytogenetic; IN VITRO; ESCHERICHIA COLI, STRAIN WWU

Effect type: Cell survival and gene mutation to give reversion of nutritional requirement for arginine

Frequency range: 1.70 and 2.45 GHz

Modulation: CW

Power densities: 2.45 GHz: 10 and 50 mW/cm.2

SARs: 1.70 GHz: 3 mW/g; 2.45 GHz: 15 and 70 mW/g

Exposure conditions: Single exposure of 3 to 4 hours

Abstract: The mutagenic potential of continuous wave electromagnetic radiation at 1.70 and 2.45 GHz was examined using a strain of the bacterium, E. coli, which can be used to detect both forward and reverse mutations. Log phase cultures of the E. coli strain were placed in 35-mm diameter sterile polystyrene tissue culture dishes and irradiated for 3 to 4 hours at 35 deg C. Exposures at 2.45 GHz were conducted at far-field power density levels of 10 and 50 mW/cm.2, which correspond to absorbed dose rates of 15 and 70 W/kg, respectively. Exposures at 1.70 GHz, at a near-field intensity of 88 V/m, were performed to correspond to an absorbed dose rate of 3 W/kg. Sensitivity for mutation induction was optimized by exposing the bacteria during at least one complete DNA replication cycle. Although positive controls using ultraviolet light demonstrated the expected exponential survival curve and increased mutation induction, no mutagenic activity could be demonstrated for either microwave frequency under the conditions employed.

Mutation: The test organism is described as requiring thymidine and 3 amino acids, proline, arginine, methionine, and tryptophan. Apparently, mutation to arginine-independence was the only variable tested.

FINAL CRITERIA: The analysis is based on determining the growth rate (expressed as number of cell doublings) and the number of arginine-independent mutants per 100 million cells at [illegible] basis, neither exposure frequency [illegible] significant increase in number of mutants over control values at any power density (up to 50 mW/cm.2) for any duration of exposure up to 4 hours. Dishes containing the cultures were exposed in an environmental chamber at 35 deg C. Control cultures were exposed at the same time as irradiated cultures, but were shielded from the radiation by being wrapped in [illegible]. There was no actual measurement of temperature

in either irradiated or control cultures during the exposure, though at the power densities employed, there must have been some rise in temperature in the irradiated cultures. While this probably does not affect the conclusion concerning absence of mutagenic effect, it opens the results to quibbling. It could be argued, for instance, that the radiation did produce mutants, but that the mutants were selectively killed by higher temperatures in the culture. In the positive control for mutation production, using UV light, exposure at between 40 and 75 J/m.2 produced 500 mutants per 100 million surviving cells per J/m.2. This exposure level may be compared with the microwave exposure levels that failed to produce any mutations.

[illegible], W. M. Nelson, E. F. Blackman, and D. J. Brusick
[illegible] GENETIC RESPONSE TO 2.45-GHZ CW AND 8.5- TO
[illegible] MICROWAVES)
[illegible], J. Microwave Power, Vol. 14, No. 3,
[illegible]

[illegible] and cytogenetic, IN VITRO;
[illegible], STRAIN D4, AND SALMONELLA TYPHIMURIUM,
[illegible] TA-[illegible], TA-[illegible], AND TA-98

[illegible] 2.45 GHz and 8.5-9.6 GHz
[illegible] GHz: CW; 8.5-9.6 GHz: pulsed
[illegible] GHz, 20 mW/cm.2; 8.5-9.6 GHz, 1-45
[illegible]
[illegible] 8.5-9.6 GHz, not stated
[illegible] exposure of 90 min for Salmonella
[illegible] at either frequency.
[illegible] of the yeast Saccharomyces
[illegible] TA-535, TA-100, and TA-98 of the
[illegible] typhimurium, were exposed to 2.45-GHz
[illegible] to 9.6-GHz pulsed electromagnetic
[illegible] power densities from 1 to 45
[illegible] during radiation was maintained at 30
[illegible] and at 37 deg C for bacterial
[illegible] revealed no increase in mutations or of
[illegible] when cells were radiated for two hours
[illegible] decreased viability of cells was noted in all
[illegible] radiation at power densities of 30
[illegible], however, no reliable changes in genetic

[illegible] through the abstract and the methods
[illegible] temperatures were maintained at 30 and 37
[illegible] but the temperature in the yeast
[illegible] at 32 deg during irradiation at 9.0 GHz.
[illegible] power irradiations were not stated.
[illegible] are casual about statistics. They
[illegible] number of mutations per
[illegible], but nowhere is there a
[illegible] number of plates counted or mutations
[illegible] the effects of microwaves in terms of
[illegible] times to effect in control, and state
[illegible] 3.0 is normal, a ratio of 2.0 to 3.0
[illegible] than 3.0 indicates mutagenic
[illegible] not justify such a procedure by
[illegible] science. Review of the effects of
[illegible] ammonia (Tables 4, 5, and 6) shows
[illegible] of mutations for irradiated cells is
[illegible] that of controls, and in the case of
[illegible] 45 mW/cm.2, the difference may be
[illegible] conclusions of the authors.

Results at 45 mW/cm.2 for TA-1535 and TA-98 cells are not given. The conclusions of the study, that microwaves do not induce mutations, would be much stronger if enough data on culture temperatures and mutation counts were included.

Hamnerius, Y., H. Olofsson, A. Rasmuson, and B. Rasmuson
A NEGATIVE TEST FOR MUTAGENIC ACTION OF MICROWAVE RADIATION IN DROSOPHILA MELANOGASTER
0165-1218/79/0011-0217, Mutation Res., Vol. 68, No. 2, pp. 217-223 (1979)
Study type: (2) Mutagenic and cytogenetic; IN VIVO; DROSOPHILA MELANOGASTER
Effect type: Somatic mutation
Frequency/wavelength: 2.45 GHz
Modulation: CW
Power Densities: Not stated
SAR: 100 W/kg
Exposure conditions: Single exposure of 6 hours duration to 1-2 day old embryos
AUTHOR ABSTRACT: Microwave radiation (2450 MHz CW) was tested for mutagenicity in Drosophila melanogaster. Embryos in water were exposed to the electromagnetic field with a mean specific absorption rate of 100 W/kg. A sensitive somatic test system was used, in which mutagenicity was measured as the frequency of somatic mutations for eye pigmentation. With the test system used, microwaves did not show any mutagenic activity.
OTHER INFORMATION: A detailed description of the design of the exposure chamber is given. The chamber appears to be very suitable for microwave irradiation of this type of material.
FINAL CRITIQUE: This is an excellently designed and executed piece of research. All confounding parameters, including temperature rise, have been adequately controlled. The study includes ionizing radiation as a positive control. A dose of 1000 rad produced mutations in 2.75% of the animals. The authors estimate that the mutagenic effect of as little as 50 rad would have been reliably detected under the conditions of the test. The absence of mutagenic effect of the microwaves in this test is highly credible.

Ray, T. L., E. C. Beyer, and C. F. Reichelderfer
MICROWAVE EFFECTS ON REPRODUCTIVE CAPACITY AND GENETIC TRANSMISSION IN DROSOPHILA MELANOGASTER
J. Microwave Power, Vol. 7, No. 2, pp. 75-82 (1972)
Study type: (2) Mutagenic and cytogenetic; IN VIVO; DROSOPHILA MELANOGASTER
Effect type: Reproductive characteristics; recessive lethal mutation
Frequency/wavelength: 2.45 GHz
Modulation: CW (?)
Power Densities: 6.5, 5.9, and 4.6 W/cm.2 (computed)
SAR: Not stated
Exposure conditions: Single exposure of 45 min duration to 0-24 hour old males
AUTHOR ABSTRACT: In order to assess potential viability and genetic alterations from microwaves, male fruit flies (D. melanogaster) were exposed to 2450 MHz radiation within 24 hours after eclosion. Three separate groups of five flies contained in acrylic capsules were placed at an 18 cm target to aperture distance for a 45-minute period with forward powers of 2.1 kW, 2.75 kW, and 3.0 kW, respectively. Immediately post-exposure, each male was mated with two Muller-5 virgin females. Each male was removed every 24 hours and remated with two additional Muller-5 virgins serially for 15 days. Generation times were observed, and each brood was scored for numbers of males and females on day 17. The generation times were similar for irradiated and controls. The ratio of males to females showed an equivalence among the control, 2.75 kW and 3.0 kW groups. There was a significant increase in ratio of males to females in the 2.1 kW group. The Muller-5 cross was carried through an F-2 to evaluate recessive lethal mutagenesis. Ten controls and fifty irradiated F-1 pairs from the total daily broods were randomly mated. The numbers of irradiated "X" chromosomes evaluated allowed detection at frequencies greater than 1%. No recessive lethal mutations were found at that level of detection.
OTHER INFORMATION: Power densities used for exposure of the flies at 18 cm were determined by measuring the values at 200 cm from the horn and applying gain correction factors that ignored the oscillatory on-axis variations of power density with distance in the near field.
FINAL CRITIQUE: There is no discussion by the authors of the temperature rise in the flies produced by the rather considerable power densities applied over a fairly long time span. In the introduction they cite a study in which the larvae of Drosophila were exposed to 0.3 and 1.0 W/cm.2 radiation at 2.45 GHz. Without special provision for cooling the larvae, the 1.0 W/cm.2 power density killed 50% in 10 minutes. The present study does not mention cooling provision

for the flies, so we presume that none was provided. The results suggest that the adult flies are considerably more heat-resistant than the larvae. For the flies exposed to 2.75 and 3.0 kW (6.5 and 5.9 W/cm.2), there was no effect of the radiation on brood time, brood size, or sex ratio of the brood. For the flies exposed to 2.1 kW (4.6 W/cm.2) the number of females in the broods was higher than expected at all breeding days except the second day after irradiation. The statement in the abstract is that the number of females was lower than expected. Genetic damage to the X-chromosomes in the exposed males would reduce the expected number of females; hence, the finding of increased number of females demonstrates the absence of damage to the X-chromosome. F-1 progeny were mated to detect recessive mutations in the F-2 generation. No mutations were found. It can be concluded that the microwave radiation at 2.45 GHz was nonmutagenic for Drosophila, down to the limit of detection (circa 1%).

Varma, M. M., and E. A. Traboulay, Jr.
EVALUATION OF DOMINANT LETHAL TEST AND DNA STUDIES IN MEASURING MUTAGENICITY CAUSED BY NON-IONIZING RADIATION
In C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010, pp. 386-396 (1976)
Study type: (2) Mutagenic and cytogenetic; IN VIVO; MOUSE
Effect type: Dominant lethal mutation; changes in physical properties of DNA
Frequency/wavelength: 1.7 GHz; 0.985 GHz
Modulation: CW
Power Densities: 10, 50 mW/cm.2
SAR: Not given
Exposure conditions: 50 mW/cm.2 for 30 min, 1.7 GHz; 10 mW/cm.2 for 80 min, 1.7 GHz; 10 mW/cm.2 for 80 min, 0.985 GHz
AUTHOR ABSTRACT: Fifty six-day-old Swiss mice were exposed to microwave radiation. In total, two dominant lethal tests (DLT) and three DNA studies were conducted. Two separate DLT and DNA studies were performed at 1.7 GHz. The testes of the animals were exposed at 50 mW/cm.2 for 30 minutes, and at 10 mW/cm.2 for 80 minutes. In the third experiment, DNA studies were conducted at 0.985 GHz, 10 mW/cm.2 for 80 minutes. In the dominant lethal test, mice exposed to 1.7 GHz, 50 mW/cm.2, showed that mutagenicity was significant at the 99 percent level in the fourth, fifth, and sixth weeks. The parallel DNA study showed a change in the Tm from 87 deg C in the control to 85 deg C in the irradiated group, with subsequent changes in the based composition, and asymmetry ratio. In the second dominant lethal test, mutagenicity was significant at the first 99 percent level in the fifth week and at the 95 percent level in the first, second, third, and sixth weeks. The parallel DNA study showed changes in the Tm, base composition, and asymmetry ratio. The third DNA study showed similar changes. The change in the optical density of the irradiated DNA supports the possibility that irradiation causes strand separation and reflects a decrease in hydrogen.
OTHER INFORMATION: Irradiation was performed in an anechoic chamber. The author describes methodology for determining power density at near-field distances.
FINAL CRITIQUE: The tables contain some errors of tabulation. In addition, the value of chi-square for differences between experimental and control values is incorrectly calculated, and the chi-square limit values for 5% probability are incorrectly stated. When the values of chi-square are correctly calculated, there is a significant difference between experimental and control values for the overall study at both 50 mW/cm.2 for 30 min and 10 mW/cm.2 for 80 min (1.7 GHz), but not for most of the individual weeks post-irradiation.

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caused only a [illegible]
during exposure [illegible]
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markedly reduces [illegible]
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a substantial [illegible]
cannot be [illegible]
animals exposed [illegible]
the paper, [illegible]
dominant [illegible]
represent [illegible]
rather than [illegible]
chromosome [illegible]
significance of [illegible]
The authors [illegible]
composition [illegible]
after irradiation [illegible]
relation to [illegible]
assay include [illegible]
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Varma, M. M., E. L. Dage, and S. R. Joshi
MUTAGENICITY INDUCED BY NON-IONIZING RADIATION IN SWISS MALE MICE
In C. C. Johnson and M. Shore (eds.), BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication (FDA) 77-8010), pp. 397-405 (1976)
Study type: (2) Mutagenic and cytogenetic; IN VIVO; MOUSE
Effect type: Dominant lethal mutations
Frequency/wavelength: 2.45 GHz
Modulation: CW
Power Densities: 100, 50 mW/cm.2
SAR: Not given
Exposure conditions: 10 min exposures; 100 mW/cm.2 1 time; 50 mW/cm.2 3 times in 1 day or 4 times in 2 weeks
AUTHOR ABSTRACT: Testes of male mice were irradiated with microwaves at 2.45 GHz in three experiments: (1) at 100 mW/cm.2, a single exposure of 10 minutes; (2) at 50 mW/cm.2, three exposures of 10 minutes each in one day; and (3) at 50 mW/cm.2, four exposures of 10 minutes each during two weeks. Treated males were tested by the dominant lethal assay for mutagenicity by mating them with untreated females for six weeks. Fertility was impaired following irradiation but mutagenicity induced was significantly higher subsequent to single exposure and multiple exposures during one day. No effects were observed when multiple exposures were extended over a period of two weeks, suggesting that high-level acute exposures are potentially more hazardous than chronic exposures at lower power densities.
OTHER INFORMATION: None
FINAL CRITIQUE: There were some deaths during exposure 5/15 at 100 mW/cm.2, 5/16 at 50 mW/cm.2 3 times in 1 day, and 3/24 at 50 mW/cm.2 4 times in 2 weeks. The authors do not discuss the cause of death. The animals were supposedly shielded from microwave exposure except for the testes, so the deaths may have been due to other causes. There is no mention of deaths in controls. There appears to be an error in the computation of chi-square for the difference in incidence of mutations between irradiated and control groups. When the values of chi-square were recalculated by the reviewer from the data shown, there were no significant differences between irradiated and control animals at any of the dose schedules employed, either overall or at individual weeks post-exposure.

TERATOGENIC AND DEVELOPMENTAL ABNORMALITIES

List of Analyses

Burdeshaw, J. A. and S. Schaffer
FACTORS ASSOCIATED WITH THE INCIDENCE OF CONGENITAL ANOMALIES: A LOCALIZED INVESTIGATION
Final Report, Report No. XXIII, 24 May 1973-31 March 1976, Contract No. 68-02-0791, EPA 600/1-77-016 (March 1977) (See "Epidemiologic" for analysis.)

Pearock, P. B., J. W. Simpson, C. A. Alford, Jr., and E. Saunders
CONGENITAL ANOMALIES IN ALABAMA
J. Med. Assoc. Ala., Vol. 41, No. 1, pp. 42-50 (1971) (See "Epidemiologic" for analysis.)

(4) OCULAR

List of Analyses

[illegible], B., [illegible], R. O. Kinion, M. Soles, [illegible], and P. M. Neidlinger
MICROWAVE LENS EFFECTS IN HUMANS
[illegible], Vol. 93, pp. 257-258 (1975)

[illegible], A. W. Guy, I. B. McDougall, and L.-F. Han
[illegible] AND PULSED CHRONIC MICROWAVE EXPOSURE ON
[illegible]
[illegible] SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF
[illegible] WAVES, Helsinki, Finland (1978) (See "Nervous
[illegible]

[illegible] Pasternack
[illegible] IN MICROWAVE WORKERS--A STATISTICAL STUDY
[illegible], Vol. 12, pp. 23-29 (1966)

[illegible], and G. W. Beebe
[illegible] WORKERS
[illegible], pp. 179-181 (1965)

[illegible], and A. F. Emery
[illegible] THE RABBIT EYE
[illegible] Microwave Theory and
[illegible] 491-498 (1975)

[illegible], S. T. Elder,
[illegible]
[illegible] AFTER REPEATED EXPOSURE OF
[illegible] MICROWAVES
[illegible] Microwave Power, Vol. 14, No. 1,
[illegible]

[illegible]
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO
ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)
[illegible], Vol. 23, No. 8, pp. 265-271,
[illegible]
[illegible] (See "Epidemiologic" for analysis.)

(4) OCULAR

List of Analyses (continued)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

Siekierzynski, M.
A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 273-280 (1974) (See "Epidemiologic" for analysis.)

Analyses under

(4) OCULAR

Aonlet[illegible], [illegible], S. [illegible], R. O. Kinion, M. Soles, G. C. McCrossan, and R. M. Neidlinger

MICROWAVE LENS EFFECTS IN HUMANS

Arch. Ophthalmol. Vol. 93, pp. 257-258 (1975)

Study type: (4) Ocular, (1) Epidemiologic; IN-VIVO; HUMANS

Effect type: Ocular opacities, vacuoles, and posterior subcapsular iridescence

Frequency/wavelength: Not quantified

Modulation: Not quantified

Power Densities: Unknown

SAR: Unknown

Exposure conditions: Not quantified

AUTHOR ABSTRACT: Individuals selected on the basis of likelihood of occupational exposure to microwaves were subjected to a biomicroscopic examination of the lens. Control personnel were also examined along with them, the examiners having no knowledge of the exposure history of any examinee [illegible] during the examination. Objective evidence of lens [illegible]mality (opacities, vacuoles, or posterior subcapsular iridescence) was recorded and a comparison made between the two groups on the basis of that evidence. The comparison showed the two groups to be essentially the same and did not support the [illegible] that [illegible] lens damage is occurring in the [illegible] environment in this country. Instead, it tended to support the assumption that the existing safety level of 10 mW/[illegible] is adequate.

OTHER INFORMATION: The results presented in this paper were based on pooled data for military and civilian personnel ([illegible] test and 801 control subjects) at five Army stations [illegible] microwave equipment. The test and control [illegible] station were selected by the local director of [illegible] programs. Each subject was scored by the [illegible] ophthalmologists for the presence or absence of each of the [illegible] physical signs rather than on magnitude scales.

CRITIQUE: As with other retrospective epidemiologic studies of RFR effects, quantitative information on RFR exposure (frequencies, power densities, durations, and other [illegible] conditions) is lacking. At best, it can be said that [illegible] test groups probably were exposed to [illegible] RFR (higher power densities and longer [illegible]) than those in the control groups, and that it is [illegible] any subject in either group was ever exposed to an average power density exceeding 10 mW/cm.2.

[illegible]

Cleary, S. F. and B. S. Pasternack
LENTICULAR CHANGES IN MICROWAVE WORKERS-A STATISTICAL STUDY
Arch. Environ. Health, Vol. 12, pp. 23-29 (1966)
Study type: (4) Ocular, (1) Epidemiologic; IN-VIVO; HUMAN
Effect type: Ocular damage from occupational exposure to RFR
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: Occupational exposure at 16 microwave installations
AUTHOR SUMMARY: An analysis of the relative incidence of lens changes in a sample of microwave workers and a control sample revealed a statistically significant increase in rate of accumulation of specific types of defects in the lenses of microwave workers. It was also noted that specific areas of microwave work specialization differ in regard to incidence of lens defects and correlations with microwave exposure parameters. Since the number of defects increased significantly with age in the control group as well as in the group of microwave workers, this process may be interpreted as indicating lens aging. Occupational exposure to microwave radiation may be implicated as a stress which increases the rate of lens aging although it is impossible at present to relate this effect to functional impairment such as loss of visual acuity or cataracts. Further investigations of the basic mechanisms of cataract induction, as mediated by exposure to electromagnetic radiation, are necessary to determine the significance of the relationship between occupational exposure and lens damage.
OTHER INFORMATION: Detailed occupational histories were obtained for currently employed personnel at 16 microwave installations by using a microwave questionnaire. A group of 736 workers occupationally exposed to RFR was selected for study, and another group of 559 individuals from the same locations and occupational environments (other than RFR) was selected for control. Both groups were given slit-lamp examinations and each person was graded for subcataractous lens changes classified as minute defects, opacification, posterior polar defects, relucency, and sutural defects on a scale from 0 for insignificant changes to 3 for large numbers of changes. An eye score consisting of the unweighted sum of scores for each type of defect was calculated. A relative exposure score was assigned, based on weights given to the types of microwave equipment involved, distance from equipment during operation, duration of work with each type, and other relevant characteristics. Statistical treatment of the data indicated that the age distribution of the exposed group differed significantly from the control group and that both groups

[illegible] physiological aging of the lens, as determined from [illegible]. Nonetheless, the investigators were able to [illegible] statistically significant (at less than the 5% level) [illegible] average scores for the exposed group in opacifications [illegible] cluster of polar defects. However, they state that no [illegible] effects such as loss of visual acuity or increased [illegible] for cataract formation have been associated with [illegible] changes.

FINAL CRITIQUE: Among the major problems with this study were [illegible] in age distribution between the exposed and [illegible] and age-related lens changes in both groups. [illegible], the grading of each individual for lens changes on a 0-3 [illegible] and the use of a simple composite eye score are [illegible] measures that were evidently not associated with actual [illegible] in visual acuity in the individuals examined. Therefore, the statistical analyses based on such measures can [illegible], and the reported statistically significant [illegible] between the exposed and control groups are of [illegible] validity. Cleary et al. (1965) also performed a [illegible] retrospective epidemiologic study of radar workers, with [illegible] results.

REFERENCES: Cleary, S. F., B. S. Pasternack, and G. W. Beebe, [illegible] INCIDENCE IN RADAR WORKERS, Arch. Environ. Health, [illegible], pp. 179-181 (1965)

Cleary, S. F., B. S. Pasternack, and G. W. Beebe
CATARACT INCIDENCE IN RADAR WORKERS
Arch. Environ. Health, Vol. 11, pp. 179-181 (1965)
Study type: (4) Ocular, (1) Epidemiologic; IN-VIVO: HUMAN
Effect type: Ocular damage from occupational exposure to RFR
Frequency/wavelength: Unknown
Modulation: Unknown
Power Densities: Unknown
SAR: Unknown
Exposure conditions: In military service during World War II, and the Korean War
REVIEWER SUMMARY: This paper describes a retrospective study of cataract incidence in Army and Air Force veterans of World War II and the Korean War to determine whether such incidence may be related to occupational exposure to RFR. A preliminary study indicated that a sample of about 2,500 cataract cases and a control group of the same size would be sufficient to permit detection of a twofold increase in relative risk with a probability of 80% at the 5% level of significance. Examination of Veterans Administration hospital records yielded 2,946 veterans born after 1910 who were treated for cataracts during the period 1950-1962. A random sample of 2,164 veterans hospitalized during the same period for other ailments was selected for control. The military record of each person was abstracted to determine his military occupational specialties (MOS) which were used to categorize him as either a radar or nonradar worker. Of those with cataracts, 19 were classified as radar workers and 100 others could not be classified as the basis of their MOS; of those without cataracts, 21 were classified as radar workers and 83 others could not be classified. These numbers yielded an overall relative risk factor of 0.67, with unity representing no increase in relative risk and values larger than unity representing the degree of severity of the effect. Examination of Air Force data separately yielded a risk factor greater than 2, but at a significance level greater than 10%. The authors indicate that there were too few cases to draw any inferences. An analysis of all the data by age grouping suggests no alteration in the age-specific incidence of cataracts due to RFR exposure.
OTHER INFORMATION: The authors point out the limitations of such a retrospective analysis, e.g., the difficulties in arriving at unequivocal conclusions regarding the relationship between the agent and the ailment of interest. They also provide several reasons why the negative results obtained constitute good evidence against the importance of ordinary occupational exposure in producing cataracts, but add that these results may not represent possible risks to present-day occupational exposure levels because the equipment used then was less powerful than those in current use. In a subsequent

study (Cleary and Pasternack, 1966), an endeavor was made to assess cataractogenesis risk at then current RFR exposure levels.

FINAL CRITIQUE: Subject to the limitations of this kind of epidemiologic study, the results provide no evidence that occupational exposure to RFR because of military service is cataractogenic. Regarding the point about the current RFR power levels being higher than those used during World War II and the Korean War, it should be noted that our knowledge about RFR cataractogenesis, particularly the threshold power densities necessary, has also grown significantly, and suitable safety regulations and precautions are in effect, to avoid the occurrence of cataracts from acute RFR exposure, such as the relatively few cases documented in the literature that presumably occurred because of ignorance.

REFERENCES: Cleary, S. F. and B. S. Pasternack, LENTICULAR CHANGES IN MICROWAVE WORKERS-A STATISTICAL STUDY, Arch. Environ. Health, Vol. 12, pp. 23-29 (1966)

Guy, A. W., J. C. Lin, P. O. Kramar, and A. F. Emery
EFFECT OF 2450-MHZ RADIATION ON THE RABBIT EYE
0018-9480/75/0006-0492, IEEE Trans. Microwave Theory and Techniques, Vol. 23, No. 6, pp. 492-498 (1975)
Study type: (4) Ocular; IN-VIVO; RABBIT
Effect type: Cataractogenic thresholds, ocular SAR distributions
Frequency/wavelength: 2.45 GHz
Modulation: CW
Power Densities: 100, 200, 300 mW/cm.2
SAR: 0.92 W/kg per mW/cm.2 Pk in vitreous body
Exposure conditions: Exposure of right eyes to various combinations of power density and exposure durations, with left eyes serving as controls
AUTHOR ABSTRACT: The cataractogenic effects of near-zone 2450-MHz radiation in rabbits are presented. The power deposition pattern inside the eyes and head of rabbits has been determined using a thermocouple technique. It was found that a peak absorption of 0.92 W/kg occurred between the lens of the eye and the retina for each milliwatt/square centimeter incident. Time and power-density studies indicated a cataractogenic threshold of a 150-mW/cm.2 incident, or 138-W/kg peak absorption behind the lens for 100 min. The threshold time decreased with increasing power density. Agreement between in vivo intraocular temperature measurements and finite-element computer predictions reinforces the suggestion of a thermal mechanism for microwave-induced lens opacities.
OTHER INFORMATION: Measurements of intraocular temperature versus depth from the corneal surface were made at a constant power density, from which the SAR variation with depth was calculated. Also, temperatures were taken at a fixed depth in the vitreous body immediately after 5-min intervals of RFR exposure to: 100 mW/cm.2 for 60 min, 200 mW/cm.2 for 35-40 min, and 300 mW/cm.2 for 30-35 min. Vitreous equilibrium temperatures were reached in 15-20 min and were 41 deg C for 100 mW/cm.2 and higher for the other two power densities. A computer model of the eye that agreed well with the measurements at 100, 200, and 300 mW/cm.2 was used to determine values of intermediate power densities.
FINAL CRITIQUE: The results are in substantial agreement with those of Carpenter and Van Ummerson (1968) regarding the existence, for 2.45 GHz, of a threshold power density of about 150 mW/cm.2 for single exposures of approximately 40 to 100 min duration. Because of the reciprocal relationship between power density and exposure duration for ocular damage, this threshold value could be applicable to exposures of longer duration than 100 min. Thus, the results can be taken as evidence supporting the contention that chronic exposures (single or multiple) to power densities well below this threshold would not be

cataractogenic.
REFERENCES: 0022-2793/68/0003-0003, Carpenter R. L. and C. A. Van Ummerson, THE ACTION OF MICROWAVE POWER ON THE EYE, J. Microwave Power, Vol. 3, No. 1, pp. 3-19 (1968)

McAfee, R. D., A. Longacre, Jr., R. R. Bishop, S. T. Elder, J. G. May, M. G. Holland, and R. Gordon
ABSENCE OF OCULAR PATHOLOGY AFTER REPEATED EXPOSURE OF UNANESTHETIZED MONKEYS TO 9.3-GHz MICROWAVES
0022-2739/79/0003-0041, J. Microwave Power, Vol. 14, No. 1, pp. 41-44 (1979)
Study type: (4) Ocular; IN-VIVO; MACACA MULATTA
Effect type: Cataractogenesis
Frequency/wavelength: 9.31 GHz
Modulation: 0.5 microsec pulses
Power Densities: 150 mW/cm.2 Av; 286 W/cm.2 Pk
SAR: Greater than 15 mW/g in saline phantoms
Exposure conditions: Daily exposures of up to 20 minutes for a total of 30 to 40 sessions over several months
AUTHOR ABSTRACT: Unfettered monkeys (Macaca mulatta) have been trained to expose the face and eyes to pulsed microwave radiation at a frequency of 9.31 GHz and an average power density of 150 mW/cm.2. Performance of an operant response required the monkeys to maintain the head within the field of the radiation source. Twelve monkeys were individually irradiated during 30 to 40 sessions and then were observed for a period of one year. No deleterious effects such as cataracts have been observed.
OTHER INFORMATION: Although the 12 monkeys were divided into irradiated and control groups of 6 each, both groups were irradiated. The authors indicate that an additional group of 75 monkeys that were not irradiated or sham-irradiated is serving as the control population for cataractogenesis.
FINAL CRITIQUE: No cataracts or corneal lesions were seen in any of the 12 irradiated animals up to 12 months after exposure. Because the findings were negative, the lack of a sham-irradiated group is not as important than if positive effects were obtained. Based on the information furnished, which does not indicate specific exposure durations per session, temperature elevations in the eye cannot be estimated with any confidence. The authors cite a 3 deg C rise in 150 ml of saline for 15 min of exposure. Even if this result is taken as a coarse estimate of mean ocular temperature rise in a monkey, such a temperature increase would be unlikely to cause thermal ocular damage. (Guy et al., 1975, provide evidence that a rise of at least 5 deg C is necessary.) The primary contribution of this research is the finding of no ocular damage in unconstrained, unanesthetized monkeys from multiple exposures to pulsed RFR (9.3 GHz) for a mean duration of about 15 min per session and totals of 30 to 40 sessions (one per day) at an average power density of 150 mW/cm.2. This value is within the range of cataractogenesis thresholds for single exposures of rabbits to CW RFR at 2.45 GHz for durations up to 100 min (Guy et al., 1975; Carpenter and Van Ummerson, 1968).

It should be noted that the locus of maximum temperature in the eye, not determined in this investigation, would be closer to the surface of the eye for 9.3 GHz than for 2.45 GHz.

REFERENCES: 0022-2739/68/0003-0003: Carpenter, R. L. and C. A. Van Ummerson, THE ACTION OF MICROWAVE POWER ON THE EYE, J. Microwave Power, Vol. 3, No. 1, pp. 3-19 (1968)
0018-9480/75/0006-0492: Guy, A. W., J. C. Lin, P. O. Kramar, and A. F. Emery, EFFECT OF 2450-MHZ RADIATION ON THE RABBIT EYE, IEEE Trans. Microwave Theory and Techniques, Vol. 23, No. 6, pp. 492-498 (1975)

(5) NERVOUS SYSTEM (General)

List of Analyses

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHz RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 52-57 (1974) (See "Epidemiologic" for analysis.)

Klimkova-Deutschova, E.
NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 268-272 (1974) (See "Epidemiologic" for analysis.)

Pazderova, J.
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHZ)
Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, pp. 265-271 (1971). English translation: JPRS No. UDC 616-001.228.1-057-07 (1971) (See "Epidemiologic" for analysis.)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

Siekierzynski, M.
A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 273-280 (1974) (See "Epidemiologic" for analysis.)

(5) NERVOUS SYSTEM (Auditory Effect)

List of Analyses

Cain, C. A. and W. J. Rissman
MAMMALIAN AUDITORY RESPONSES TO 3.0 GHz MICROWAVE PULSES
0018-9294/78/0500-0288, IEEE Trans. Biomed. Eng., Vol. 25, No. 3, pp. 288-293 (1978)

Chou, C.-K. and R. Galambos
MIDDLE-EAR STRUCTURES CONTRIBUTE LITTLE TO AUDITORY PERCEPTION OF MICROWAVES
0022-2739/79/0012-0321, J. Microwave Power, Vol. 14, No. 4, pp. 321-326 (1979)

Chou, C.-K. and A. W. Guy
MICROWAVE-INDUCED AUDITORY RESPONSES IN GUINEA PIGS: RELATIONSHIP OF THRESHOLD AND MICROWAVE-PULSE DURATION
0048-6604/79/1112-S029, Radio Sci., Vol. 14, No. 6S, pp. 193-197 (1979)

Chou, C.-K., A. W. Guy, and R. Galambos
CHARACTERISTICS OF MICROWAVE-INDUCED COCHLEAR MICROPHONICS
0048-6604/77/1112-S030, Radio Sci., Vol. 12, No. 6S, pp. 221-227 (1977)

Foster, K. R. and E. D. Finch
MICROWAVE HEARING: EVIDENCE FOR THERMOACOUSTIC AUDITORY STIMULATION BY PULSED MICROWAVES
Science, Vol. 185, pp. 256-258, 19 July 1974

Frey, A. H. and E. Coren
HOLOGRAPHIC ASSESSMENT OF A HYPOTHESIZED MICROWAVE HEARING MECHANISM
0036-8075/79/1012-0232, Science, Vol. 206, pp. 232-234, 12 Oct 1979

Frey, A. H. and R. Messenger, Jr.
HUMAN PERCEPTION OF ILLUMINATION WITH PULSED ULTRAHIGH-FREQUENCY ELECTROMAGNETIC ENERGY
Science, Vol. 181, pp. 356-358, 27 July 1973

White, R. M.
GENERATION OF ELASTIC WAVES BY TRANSIENT SURFACE HEATING
J. Appl. Phys., Vol. 34, No. 12, pp. 3559-3567 (1963)

Analyses under

(5) NERVOUS SYSTEM (Auditory Effect)

Cain, C. A. and W. J. Rissman
MAMMALIAN AUDITORY RESPONSES TO 3.0 GHz MICROWAVE PULSES
0018-9294/78/0500-0288, IEEE Trans. Biomed. Eng., Vol. 25, No. 3, pp. 288-293 (1978)
Study type: (5) Nervous system (auditory effect); IN-VIVO; CAT, CHINCHILLA, BEAGLE, HUMAN
Effect type: Perception of pulsed RFR as sound
Frequency/wavelength: 3.0 GHz
Modulation: Pulsed
Power Densities: Various
SAR: Not measured
Exposure conditions: Auditory evoked responses to acoustic and RFR stimuli were measured for anesthetized animals. Human subjects were given RFR stimuli only, but were given standard audiograms and were also tested for binaural hearing thresholds in the 1-20 kHz range.
AUTHOR ABSTRACT: A study of the effects of 3.0 GHz microwave pulses on the auditory systems of a number of mammalian species was conducted. Some human subjects heard a distinct "click" when irradiated with a sufficiently intense individual microwave pulse. Microwave-induced auditory-evoked responses were measured in the cat, dog, and chinchilla. The microwave peak power density levels at the threshold of producing an auditory response were determined for a number of human subjects in addition to the smaller animals. The inability of some of the human subjects to hear short microwave pulses was correlated with hearing losses above 8 kHz in frequency.
OTHER INFORMATION: Two cats, two chinchillas, one beagle, and eight human volunteers were studied. For the animals, surface or brainstem-implanted electrodes were used to measure RFR- and audio-evoked responses. The evoked responses were similar for the two types of stimuli except for the transit time delay of the audio stimulus. The threshold energy density for RFR responses ranged from 8.7 to 14 microjoules/cm.2 per pulse for the cats, from 7.5 to 20 for the chinchillas, and averaged 5.0 for the beagle. For a pulse width of 10 microseconds, these values correspond to pulse power densities of 1.3 W/cm.2 for both cats, 1 and 2 W/cm.2 for the chinchillas, and 300 mW/cm.2 for the beagle. Five of the human subjects could detect 15-microsecond pulses as clicks; the other three required 20-microsecond pulses. A strong correlation between RFR perception and hearing ability above 8 kHz as determined from the binaural thresholds was noted. The average threshold energy density for the humans was 10.6 microjoules/cm.2 per pulse. For 15-microsecond pulses, this corresponds to about 700 mW/cm.2 pulse power density; however, three subjects were able to perceive 15-microsecond pulses at 300 mW/cm.2 (4.5 microjoules/cm.2 per pulse).
FINAL CRITIQUE: The presentation of data and results is in

sufficient detail to render additional analysis unnecessary. The 300 mW/cm.2 threshold value found for three of the eight human subjects can serve as a conservative value for reference purposes (e.g., for environmental assessments). Also, as the authors point out, the animal results corroborate the theoretical predictions of Lin (1976).

REFERENCES: Lin, J. C., MICROWAVE-INDUCED HEARING: SOME PRELIMINARY THEORETICAL OBSERVATIONS, J. Microwave Power, Vol. 11, No. 3, pp. 295-298 (1976)

Chou, C.-K. and R. Galambos
MIDDLE-EAR STRUCTURES CONTRIBUTE LITTLE TO AUDITORY PERCEPTION OF MICROWAVES
0022-2739/79/0012-0321, J. Microwave Power, Vol. 14, No. 4, pp. 321-326 (1979)
Study type: (5) Nervous system (auditory effect); IN-VIVO; GUINEA PIG
Effect type: Brain-stem evoked responses to RFR and audio stimuli
Frequency/wavelength: 918 MHz
Modulation: 10 microsec pulses, 30 pps
Power Densities: Not stated
SAR: 0.027 to 11.05 J/kg Av
Exposure conditions: Anesthetized animals with leads in circular waveguide; acoustical stimuli by loudspeaker
AUTHOR ABSTRACT: The contribution of the ossicles (middle-ear bones) to auditory perception of microwaves was evaluated by the brain-stem-evoked response (BER). Amplitude and latency of BERS were recorded from guinea pigs that were stimulated at various intensities by acoustic pulses coupled to the auditory canal or via bone conduction, and by microwave pulses. Blocking of the external ear, middle-ear damping, and middle-ear destruction produced little change in the BERs that were elicited by microwave pulses. Results indicate that activity in the central auditory pathway as induced by pulsed microwaves only requires stimulation of the cochlea. Conduction of pressure waves through the bones of the cranium appears to be the mechanism responsible in perception of pulsed microwaves.
OTHER INFORMATION: The right cochlea of each animal was destroyed, and the basic measurement technique was to record the amplitudes and latencies of the brain-stem-evoked responses (BERs) to RFR and acoustic stimuli by means of a pair of carbon-loaded Teflon electrodes, one of which was attached to the skin and the other to the left mastoid process. (Use of such electrodes for recording EEGs during RFR exposure is described in Chou and Guy, 1979.) The BERs were recorded after each of the following successive treatments: (1) blocking of the left external meatus with mineral-oil-soaked cotton balls, (2) alteration of the mechanical damping of the ossicular chain by filling the bulla with mineral oil, (3) destruction of the middle ear by cutting the ossicular chain and piercing the tympanic membrane, and (4) destruction of the cochlea by piercing the round window. Acoustic stimulation of all of the animals was via air conduction from a piezoelectric tweeter. In addition, for 3 animals, comparisons were made between BERs to both airborne and bone-conducted acoustic stimuli, using a piezoelectric transducer in contact with the frontal bone for the latter. Treatments (1) and (2) caused the airborne

acoustically-stimulated BERs but not the RFR-induced BERs. Treatment (3) further reduced the airborne acoustic BERs, and also reduced the bone-conducted acoustic BERs and the RFR BERs to a lesser extent than the airborne acoustic BERs. After treatment (4) (cochlea destruction), no BERs were obtained from either acoustic or RFR stimuli.

FINAL CRITIQUE: The experimental results constitute strong evidence that cochlea activation is necessary for auditory perception of pulsed RFR. The similar BERs obtained from bone-conducted-acoustic and RFR stimuli after destruction of the middle ear and the much lower BERs obtained for airborne-acoustic stimuli support the hypothesis that perception is due to transduction of RFR into acoustic waves (at unspecified locations in the head) which travel via bone conduction to the cochlea. Thus, these results lend credence to the various hypothesized RFR-to-sound transduction mechanisms and negate the hypothesis of perception by direct neural stimulation by RFR.

REFERENCES: 0022-2739/79/0012-0321, Chou, C.-K. and A. W. Guy, CARBON-LOADED TEFLON ELECTRODES FOR CHRONIC EEG RECORDINGS IN MICROWAVE RESEARCH, J. Microwave Power, Vol. 14, No. 4, pp. 321-326 (1979)

Chou, C.-K., and A. W. Guy
MICROWAVE-INDUCED AUDITORY RESPONSES IN GUINEA PIGS: RELATIONSHIP OF THRESHOLD AND MICROWAVE-PULSE DURATION
0048-6604/79/1112-S029, Radio Sci., Vol. 14, No. 6S, pp. 193-197 (1979)
Study type: (5) Nervous system (auditory effect); IN-VIVO; GUINEA PIG
Effect type: Thresholds for auditory perception of pulsed RFR
Frequency/wavelength: 918 MHz
Modulation: 10 to 500 microsec pulses at 30 pps
Power Densities: Up to 90 mW/cm.2 Av
SAR: Various
Exposure conditions: Animals with heads in circular waveguide; acoustical stimuli by loudspeaker
AUTHOR ABSTRACT: Auditory brain-stem-evoked electrical responses of guinea pigs were used to determine microwave energy thresholds for perception of pulsed radiations. A klystron was used to generate 918-MHz microwaves at pulse widths between 10 and 500 microsec; the microwaves were fed into a circular waveguide that partly enclosed a guinea pig's head. At pulse widths less than 30 microsec, thresholds were related to the density of absorbed energy (and to the density of incident energy). The minimal absorbed energy density per pulse is 5 mJ/kg. As the width of the pulse increased, the threshold energy increased. For pulses longer than 70 microsec, thresholds were related to the peak of the incident power density. The maximal power density of incident radiation is 90 mW/cm.2 in the circular waveguide. The dependence of the evoked response on the width of the microwave pulse is in excellent agreement with predictions of thermal-expansion theory. These results provide more evidence that the microwave auditory effect is caused by a thermal expansion in the exposed head.
OTHER INFORMATION: Brain-stem-evoked responses (BERs) to RFR and acoustic stimuli were detected by means of a pair of carbon-loaded Teflon electrodes, one of which was attached to the skin and the other to the mastoid process on either side. (Use of such electrodes for recording EEGs during RFR exposure is described in Chou and Guy, 1979.) Acoustic stimuli were used to verify the hearing ability of each animal. The threshold of input power for a detectable RFR-induced BER was determined for each pulse width (10 to 500 microsec), and the value was divided by the cross-sectional area of the cylindrical waveguide (about 320 cm.2) to obtain the corresponding threshold peak incident power density. Also calculated was the incident energy density per pulse for each pulse width, and the pulse repetition frequency (30 pps) was used to calculate the incident average power density. Lastly, the threshold average absorbed energy density per pulse was obtained from the

incident energy density per pulse by dividing by the mass of the animal's head.
FINAL CRITIQUE: The dependence of the threshold for RFR-induced BERs on pulse width is consistent with the results of Frey and Messenger (1973) on auditory perception of pulsed RFR by humans, and with the results of Gournay (1966) and of Foster and Finch (1974) on transduction of pulsed RFR into acoustic waves by transient thermal expansion, and therefore support that transduction hypothesis.
REFERENCES: 0022-2739/79/0012-0321, Chou, C.-K. and A. W. Guy, CARBON-LOADED TEFLON ELECTRODES FOR CHRONIC EEG RECORDINGS IN MICROWAVE RESEARCH, J. Microwave Power, Vol. 14, No. 4, pp. 321-326 (1979)
Foster, K. R. and E. D. Finch, MICROWAVE HEARING: EVIDENCE FOR THERMOACOUSTIC AUDITORY STIMULATION BY PULSED MICROWAVES, Science, Vol. 185, pp. 256-258, 19 July 1974.
Frey, A. H. and R. Messenger, Jr., HUMAN PERCEPTION OF ILLUMINATION WITH PULSED ULTRAHIGH-FREQUENCY ELECTROMAGNETIC ENERGY, Science, Vol. 181, pp. 356-358, 27 July 1973.
Gournay, L. S., CONVERSION OF ELECTROMAGNETIC TO ACOUSTIC ENERGY BY SURFACE HEATING, J. Acous. Soc. Am., Vol. 40, pp. 1322-1330 (1966)

Chou, C.-K., A. W. [illegible] and [illegible] Lambros
CHARACTERISTICS OF MICROWAVE-INDUCED COCHLEAR MICROPHONICS
[illegible], Radio [illegible], Vol. 12, No. 6S,
pp. 121-[illegible], 1977.
Type: [illegible] auditory effect); IN-VIVO;
GUINEA PIG, CAT
Effect type: RFR-ind. [illegible] microphonics
Frequency/wave length: 918, 2450 MHz
Modulation: 10 msec sec pulses, 100 pps
Power Densities: various; peak powers up to 10 kW
SAR: 0.6-1.4 J/kg for guinea pigs; 0.51-0.8 for cats
Exposure conditions: Guinea pigs and small cats with heads in rectangular waveguide; open-ended source and horn for adult cats
AUTHOR ABSTRACT: [illegible] microphonics (CM) have been recorded from guinea pigs and from cats of differing body mass during irradiation by 918- and by 2450-MHz pulsed microwaves. Both horn and [illegible] and a cylindrical waveguide exposure system were used to radiate the animals. The CM frequency and duration were similar irrespective of carrier frequency and mode of application. Parameters of the CM (except amplitude) were not influenced by orientation of the body axis to the electrical field [illegible] pulse width of microwaves for pulses less than 30 [illegible]. The frequency of the CM correlated well with the [illegible] of the brain cavity and poorly with several [illegible]. Extrapolations of these animal findings to [illegible] indicates that the frequency of the microwave-induced CM [illegible] would be between 7 and 10 kHz.
OTHER INFORMATION: [illegible] microphonics (CM) were recorded with a carbon [illegible] in contact with the round window and the [illegible] efferent electrode [illegible] proximal tissue. In the guinea pigs, the CM frequency varied inversely with body mass; in the cats, however, there was no consistent variation of CM frequency with body mass. [illegible] also noted that although the head mass, brain mass, head dimensions, skull thickness, and dimensions of the [illegible] cavity all increase with body mass, the brain cavity and [illegible] dimensions increase only slightly. Their results show that the CM frequency correlates well with the [illegible] of the brain cavity but not with the other dimensions of the head or [illegible]. The average threshold energies per pulse for [illegible] were 10 mJ/kg for adult cats, 2.5 for kittens, and 7.5 for adult guinea pigs.
FINAL CRITIQUE: The results tend to support the hypothesis that auditory perception of pulsed RFR is due to transduction of the RFR into acoustic energy, but this specific [illegible] does not offer any insight into the transduction [illegible].
REFERENCES: None

Foster, K. R. and E. D. Finch
MICROWAVE HEARING: EVIDENCE FOR THERMOACOUSTIC AUDITORY STIMULATION BY PULSED MICROWAVES
Science, Vol. 185, pp. 256-258, 19 July 1974
Study type: (5) Nervous system (auditory effect); non-biological
Effect type: RFR-induced elastic waves in water
Frequency/wavelength: 2.45 GHz
Modulation: 2-27 microsec pulses
Power Densities: 5.3 W/cm.2 Pk
SAR: Not applicable
Exposure conditions: Polystyrene tanks of various sizes containing 0.15-N KCl. A hydrophone was used for measuring peak sound pressure as a function of pulse width and filter bandwidth.
AUTHOR ABSTRACT: Acoustic transients can be thermally generated in water by pulsed microwave energy. The peak pressure level of these transients, measured within the audible frequency band as a function of the microwave pulse parameters, is adequate to explain the "clicks" heard by people exposed to microwave radiation.
OTHER INFORMATION: A theoretical treatment is given, showing that for short pulses, the peak sound pressure is proportional to the energy per pulse, whereas for long pulses, the pressure is proportional to the incident power density. The authors' experimental results indicate that the transition between the two regimes occurs for pulses of 20 to 25 microseconds duration. An interesting additional result is that the acoustic signal is not obtained in water at 4 deg C and that the polarity of the transient acoustic signal for water between 0 and 4 deg C is reversed from that for temperatures above 4 deg C.
FINAL CRITIQUE: The results of this investigation confirm those of White (1963), and as stated by the authors, the dependence of sound pressure on pulse duration and incident power density is consistent with the results at 1.245 GHz of Frey and Messenger (1973). The finding that the acoustic effect is absent for water at 4 deg C (where its expansion coefficient is essentially zero) is significant in that it indirectly supports the hypothesis that the phenomenon is produced by transient heating.
REFERENCES: Frey, A. H. and R. Messenger, HUMAN PERCEPTION OF ILLUMINATION WITH PULSED ULTRAHIGH-FREQUENCY ELECTROMAGNETIC ENERGY, Science, Vol. 181, pp. 356-358, 27 July 1973
White, R. M., GENERATION OF ELASTIC WAVES BY TRANSIENT SURFACE HEATING, J. Appl. Phys., Vol. 34, No. 12, pp. 3559-3567 (1963)

Frey, A. H. and E. Coren
HOLOGRAPHIC ASSESSMENT OF A HYPOTHESIZED MICROWAVE HEARING MECHANISM
0036-8075/79/1012-0232, Science, Vol. 206, pp. 232-234, 12 Oct 1979
Study type: (5) Nervous system (auditory effect); IN-VITRO; RAT, GUINEA PIG
Effect type: Holographic detection of tissue movement in the head in response to pulsed RFR
Frequency/wavelength: 1.1-1.3 GHz
Modulation: Pulsed
Power Densities: 1.25-8.5 W/cm.2 Pk
SAR: Not indicated
Exposure conditions: Pulse widths of 10 and 20 microsec at repetition rates of 25 and 50 pps
AUTHOR ABSTRACT: Exposure of the head to pulse-modulated microwaves induces the perception of a sound. It has been hypothesized that the electromagnetic energy is converted to acoustic energy in the skull and then conducted through the bone. Dynamic time-averaged interferometric holography showed that the predicted motion of head tissue did not occur. An alternative locus for this hearing effect is suggested.
OTHER INFORMATION: The primary objective was to try to detect pulsed-RFR-induced surface movements in the heads of experimental animals shortly after sacrifice, starting with the skin, and after successive removal of dorsal areas of skin, musculature, skull, and the brain. The authors indicate that with the holographic technique used, any movement of a surface is averaged over durations that exceed the vibrational periods of the motion. Thus a stationary surface will appear bright, and a nearby moving surface will appear dimmer, with the intensity diminution being dependent on the magnitude of the surface displacement. The authors also state that they compared holograms obtained from each animal during RFR exposure with holograms from the same surfaces of the same animal taken during sham exposure, and could not detect any differences. They concluded therefrom that motions predicted by other investigators were not produced, and suggested that the site of transduction of RFR into elastic waves is more likely to be in the cochlea itself rather than elsewhere in the head followed by transmission of the elastic waves to the cochlea by bone conduction.
FINAL CRITIQUE: The authors do not provide any specific information about the appearances of the holograms or the differences sought between holograms of RFR- and sham-exposed surfaces. Based on the meager description of the holographic technique, one would expect that the brightness of a surface having non-uniform optical reflectance would appear non-uniform even if the surface were stationary. Also, a surface having

uniform reflectance and moving as a unit, i.e., without motion of any area relative to another, would appear uniformly illuminated (but presumably of lower brightness than if the same surface were stationary). Without quantitative brightness-distribution data, it is not possible to assess the validity of these no-movement findings. A more fundamental question is whether or not the successive removal of skin, musculature, etc., would alter possible RFR-to-elastic-wave transduction. Suppose, for example, transduction takes place at the inner or outer surface of the skull with the skin and musculature intact (which may render the motion undetectable with this holographic technique). Would baring the skull by the removal of skin and musculature alter the characteristics of the transduction process significantly? In the absence of quantitative data and resolution of such queries, this reviewer believes that the results of this investigation do not vitiate those of Chou and Galambos (1979).

REFERENCES: 0022-2739/79/0012-0321, Chou, C.-K. and R. Galambos, MIDDLE-EAR STRUCTURES CONTRIBUTE LITTLE TO AUDITORY PERCEPTION OF MICROWAVES, J. Microwave Power, Vol. 14, No. 4, pp. 321-326 (1979)

Frey, A. H. and R. [illegible]
HUMAN PERCEPTION OF ILLUMINATION WITH PULSED ULTRAHIGH-FREQUENCY ELECTROMAGNETIC ENERGY
Science, Vol. 181, pp. 356-358, 27 July 1973
Study type: (5) Nervous system (auditory effect); IN-VIVO; HUMAN
Effect type: Perception of pulsed RFR as sound
Frequency/wavelength: 1.245 GHz
Modulation: 50 pulses/second
Power Densities: 90-630 mW/cm.2 Pk at 0.32 mW/cm.2 Av and 0.19-1.29 mW/cm.2 Av at 370 mW/cm.2 Pk
SAR: Not measured
Exposure conditions: Volunteers in an anechoic chamber
AUTHOR ABSTRACT: A psychophysical study of the perception of "sound" induced by illumination with pulsed-modulated, ultrahigh-frequency electromagnetic energy indicated that perception was primarily dependent upon pulse width. The average power density did not significantly affect perception. Perceived characteristics of pitch and timbre appeared to be functions of modulation.
OTHER INFORMATION: The [illegible] pulse repetition frequency (50/second) was used [illegible] experiments. In one set of experiments, the [illegible] was held constant at 0.32 mW/cm.2 [illegible] was varied from 10 to 70 microsec. In the [illegible] power density was held constant at [illegible] pulse duration was varied over the same range. [illegible] were given 3 trials each. Each subject was first presented the RFR signal for 2 seconds, the perceived loudness of which was taken as reference (100). After 5 seconds, the [illegible] was presented for 2 seconds and the subject rated its loudness relative to the reference.
FINAL CRITIQUE: [illegible] presented in the paper for each test condition are the mean value for all subjects and repetitions; [illegible] are given, so the amount of scatter cannot be [illegible]. However, subjective judgements of relative loudness [illegible] imprecise. Nevertheless, the variations of median [illegible] loudness with pulse duration at constant average power [illegible] and at constant peak power density appear to be [illegible] with theoretical models based on the transient [illegible], such as the treatment of White (1963). However, the [illegible] threshold peak power density of 80 mW [illegible] is lower than the values reported by later [illegible] Cain and Rissman (1978).
REFERENCES: 0018-92[illegible]58 Cain, C. A. and W. J. Rissman, MAMMALIAN AUDITORY RESPONSES TO 3.0 GHz MICROWAVE PULSES, IEEE Trans. Biomed. Eng., Vol. 25, No. 3, pp. 288-293 (1978)

White R. M., GENERATION OF ELASTIC WAVES BY TRANSIENT SURFACE HEATING, J. Appl. Phys., Vol. 34, No. 12, pp. 3559-3567 (1963)

W[illegible]
[illegible] TRANSIENT SURFACE HEATING
[illegible] 3559-3567 (1963)
[illegible] auditory effect);

[illegible] waves in liquids and solids

M[illegible]

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A[illegible]

[illegible] ident on various
[illegible] rystal. For the latter,
[illegible] ingle pulse was about 6
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A[illegible] a body is subjected to
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[illegible] ed as a result of surface
[illegible] This process is analyzed,
wit[illegible] e of an input heat flux
var[illegible], to relate the elastic wave
[illegible] of the input flux and the
thermal [illegible] of the body. Experiments
performed [illegible] mpact and rf absorption verify
the [illegible] wave amplitude and the
absorbed power density, and correlate well with the thermal and
elastic properties of the heated medium. Comparison of the
elastic wave stress amplitude with radiation pressure shows
that the former may be much greater than the latter, as
experiments have demonstrated. When a barium titanate crystal
was used to detect the elastic waves produced, heating by a
single 2 microsec pulse of electrons or microwave radiation
produced easily detectable signals at power levels down to 2
W/cm.2, corresponding to a computed peak surface temperature
rise of about 0.001 deg C, and produced piezoelectric crystal
voltages ranging from about one to more than 60 mV/kW/cm.2
absorbed power density.
OTHER INFORMATION: A comprehensive theoretical treatment of
the conversion of RFR pulses into elastic waves based on
transient heating is given. Elastic waves were detected in all
metals tested, in several carbon-loaded plastics, in water, and
in a silver-coated barium titanate piezoelectric crystal.
Mixing (production of beat frequencies) was observed when two
pulses of different RFR frequencies were simultaneously
absorbed.
FINAL CRITIQUE: This is an important early paper cited by
later investigators of the RFR auditory effect. Most notable
is the calculation that absorption of a 2 microsecond pulse

of 2 W/cm.2 peak power density would yield a temperature rise of only about 0.001 deg C.

REFERENCES: None

(5) NERVOUS SYSTEM (Blood-Brain Barrier)

List of Analyses

Albert, E. N.
REVERSIBILITY OF MICROWAVE-INDUCED BLOOD-BRAIN BARRIER PERMEABILITY
0048-6604/79/1112-S048, Radio Sci., Vol. 14, No. 6S, pp. 323-327 (1979)

Frey, A. H., S. R. Feld, and B. Frey
NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP
Ann. N. Y. Acad. Sci., Vol. 247, pp. 433-439 (1975)

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STUDIES ON BLOOD-BRAIN BARRIER PERMEABILITY AFTER MICROWAVE RADIATION
0301-634X/78/0015-0367, Rad. and Environ. Biophys., Vol. 15, pp. 367-377 (1978)

Oscar, K. J. and T. D. Hawkins
MICROWAVE ALTERATION OF THE BLOOD-BRAIN BARRIER SYSTEM OF RATS
Brain Res., Vol. 126, pp. 281-293 (1977)

Oscar, K. J., S. P. Gruenau, M. T. Folker, and S. I. Rapoport
LOCAL CEREBRAL BLOOD FLOW FOLLOWING MICROWAVE EXPOSURE
Presented at the Bioelectromagnetics Symposium, U. of Washington, Seattle, WA, 18-22 June 1979

Rapoport, S. I., K. Ohno, W. D. Fredericks, and K. D. Pettigrew
A QUANTITATIVE METHOD FOR MEASURING ALTERED CEREBROVASCULAR PERMEABILITY
0048-6604/79/1112/S051, Radio Sci., Vol. 14, No. 6S, pp. 345-348 (1979)

Spackman, D. H., V. Riley, A. W. Guy, and C.-K. Chou
STUDIES OF RF RADIATION EFFECTS ON BLOOD-BRAIN BARRIER PERMEABILITY USING FLUORESCEIN AND AMINO ACIDS
Presented at the Open Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, 1-8 August 1978

Analyses under

(5) NERVOUS SYSTEM (Blood-Brain Barrier)

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USAFSAM REVIEW AND ANALYSIS OF RADIOFREQUENCY RADIATION BIOEFFE--ETC(U)
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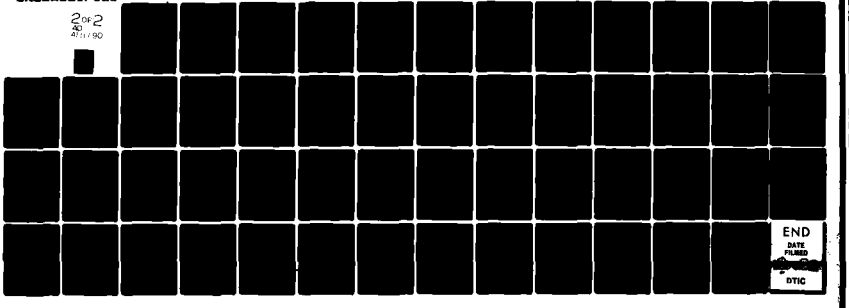

Albert, E. N.
REVERSIBILITY OF MICROWAVE-INDUCED BLOOD-BRAIN BARRIER PERMEABILITY
0048-6604/79/1112-S048, Radio Sci., Vol. 14, No. 6S, pp. 323-327 (1979)
Study type: (5) Nervous system (blood-brain barrier); IN-VIVO; CHINESE HAMSTER, RAT
Effect type: RFR-induced blood-brain barrier permeability
Frequency/wavelength: 2.8 GHz
Modulation: CW
Power Densities: 10 mW/cm.2
SAR: not given
Exposure conditions: near-field exposure for 2 hours
AUTHOR ABSTRACT: Ultrastructural studies have revealed increased permeation of the blood-brain barrier by protein in Chinese hamsters after exposure to 2450-MHz microwaves (CW) at 10 mW/cm.2. Reversibility of this microwave-induced permeability in microvasculature of Wistar rats and Chinese hamsters was assessed. The animals were anesthetized and their heads were irradiated in the near field with 2800-MHz CW microwaves at 10 mW/cm.2 for two hours. Horseradish-peroxidase protein was injected as a tracer to study its transport across capillaries in all regions of the brain. Gross- and electron-microscopic observations indicated that the relative impermeability of the blood-brain barrier is re-established within two hours after irradiation. A significant but incomplete increase of permeability was observed one hour after exposure. Preliminary data indicate that the blood-ocular barrier was similarly affected.
OTHER INFORMATION: Of the 52 animals (34 Chinese hamsters and 18 rats) exposed to RFR, 30 were euthanized immediately, 11 at 1 hour after exposure, and 11 at 2 hours after exposure. An additional group of 20 animals (12 hamsters and 8 rats) was sham-irradiated. Leakage of horseradish peroxidase (HRP), which yields a dark-brown reaction product, was scored by two independent individuals on a 5-point scale. Increased BBB permeability in some brain regions was reported for 17 of the 30 animals euthanized immediately after RFR exposure and for 4 of the 20 sham-irradiated animals. Fewer areas of increased permeability were evident for animals euthanized 1 hour after RFR exposure than for those euthanized immediately, and except for 1 rat, virtually no leakage of HRP was seen for the animals euthanized 2 hours after RFR exposure. The investigator also reports preliminary results with hamsters indicating that when HRP was injected after RFR exposure, some reaction product was seen in the extracapillary spaces of the iris. Also, the cytoplasm of endothelial cells of the iris capillaries was filled with pinocytotic vesicles containing HRP.
FINAL CRITIQUE: Perhaps the most puzzling aspect of this

investigation is the result that 4 of the 20 sham-irradiated animals yielded evidence of increased BBB permeability. The investigator does not elaborate this point either qualitatively or statistically. Such a result can be interpreted as indicating that other factors in the experimental procedure could alter the BBB. The apparently anomalous increased BBB permeability in 1 rat euthanized 2 hours after RFR exposure supports this surmise. A possible factor that could confound results obtained with injected HRP is the existence of endogenous peroxidase. Because of these uncertainties, it is difficult to evaluate the validity of the findings of this investigation.

REFERENCES: none

Frey, A. H. , S. R. Feld, and B. Frey
NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP
Ann. N.Y. Acad. Sci., Vol. 247, pp. 433-439 (1975)
Study type: (6) Behavioral, (5) Nervous system (blood-brain barrier); IN-VIVO;RAT
Effect type: RFR-avoidance response in shuttle box; RFR-induced blood-brain barrier permeability
Frequency/wavelength: 1.2 GHz
Modulation: Pulsed and CW
Power Densities: Pulsed: 2.1 mW/cm.2 Pk, 0.2 mW/cm.2 Av; CW: 2.4 mW/cm.2
SAR: Not given
Exposure conditions: Pulsed: 2.5 ms pulsewidth, 1000 pps (0.5 duty cycle); each animal given 4 sessions of 30 min of pulsed, CW, or sham exposure, 1 exposure session per day on 4 successive days.
AUTHOR ABSTRACT: Over the years, this laboratory has studied radio-frequency (rf) energy effects, such as evoked potentials in the brains of cats, visual evoked responses in cats and monkeys, frog heart arrhythmia, and hearing phenomena in cats and humans. A few years ago, one of us (A.H.F.) discussed the possible mechanisms by which rf could affect biologic systems in general and the nervous system in particular. The possibilities considered and evaluated included rf energy-induced transmembrane potential changes, conformational changes in membranes, rf field-induced forces at the neural junction, microthermal effects, and also possible rf effects on tissue thought to have electret characteristics or piezoelectric properties. The solid-state characteristics of the nervous system were regarded within the context of possible rf energy-induced effects, and these possibilities were evaluated. Other possibilities were also contemplated. The evaluation was concluded with the observation that, "The question is not whether there is a possible mechanism, but rather which of numerous possible mechanisms...." In the work reported here, we made a first approach to answering the question and began to define the relationship between neural function and behavior. We have used essentially the same rf energy parameters in experiments that involved avoidance behavior and brain tissue permeability change as indexed with a fluorescent dye. We found an association between changes in behavior and in brain permeability. We have also found a difference in effectiveness of pulsed and continuous energy on behavior and brain permeability. We wish to make quite clear that we have not established a causal relationship, only an association.
OTHER INFORMATION: For the behavior experiment, half of the shuttle box was shielded against RFR, and the fraction of the time each rat spent in the unshielded half during each exposure

session was recorded. For the first 2 daily sessions, all three groups (pulsed-, CW-, and sham-exposed) spent approximately 60% in the unshielded half, with no statistically significant differences among the groups. However, for the other 2 daily sessions, the pulsed group spent only 30% in that half, the CW group 64%, and the sham group 52%, with the differences between the pulsed and the other two groups being statistically significant; the difference between the CW and sham groups was not significant. A total of 18 rats was used in this experiment. Sodium fluorescein was the tracer used in the brain experiment. Ninety rats were divided into 15 groups, which were used for the three exposure conditions (pulsed, CW, sham) in 5 head positions. The fluorescein was injected after exposure and allowed to circulate for 5 min, after which the rat was exsanguinated and its brain was removed, embedded, and sliced into 28 sections. The sections were examined under ultraviolet and fluorescence was scored visually on a scale of 0 to 3. Significant differences were reported among all three exposure conditions. The broadside head position (relative to the RFR source) showed virtually no fluorescence under all three exposure conditions.

FINAL CRITIQUE: The data presented for the behavioral experiment are insufficient to permit analysis of the validity of the conclusions. Specifically, it is unclear why the investigators presented only the combined data for the first two days and for the second two days instead of the data for each of the four days. Also, because all three groups spent 60% of the session time in the unshielded half of the shuttle box during the first two days (which might be interpreted as indicating some preference for that half irrespective of the presence or absence of RFR), it is difficult to draw any inferences regarding the 30% spent there by the pulsed group during the second two days. The results of the brain experiment indicate that RFR exposure induces the uptake of fluorescein in the brain, with pulsed RFR being more effective than CW. Again, however, details are lacking regarding the statistical treatment of the data and the rationale therefor. The implication of the results is that fluorescein leaked from the vascular system of the brain into the parenchyma (blood-brain-barrier permeation) but no morphological information is presented. The question of possible artifact can be raised because the presence of fluorescein was detected in some sham-exposed specimens. Also, endeavors by subsequent investigators to replicate this experiment with more objective and refined detection methods (Merritt et al., 1978) yielded negative results.

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Merritt, J. H., A. F. Chamness, and S. J. Allen,
0301-634x/78/0015-0367 STUDIES ON BLOOD-BRAIN BARRIER

PERMEABILITY AFTER MICROWAVE-RADIATION, Rad. and Environ. Biophys., Vol. 15, pp. 367-377 (1978)

Merritt, J. H., A. F. Chamness, and S. J. Allen
STUDIES ON BLOOD-BRAIN BARRIER PERMEABILITY AFTER MICROWAVE-RADIATION
0301-634X/78/0015-0367, Rad. and Environ. Biophys., Vol. 15, pp. 367-377 (1978)
Study type: (5) Nervous system (blood-brain barrier);
IN-VIVO; RAT
Effect type: RFR-induced blood-brain barrier permeability
Frequency/wavelength: 1.2-1.3 GHz
Modulation: Pulsed and CW
Power Densities: 2-75 mW/cm.2 Pk, 1-38 mW/cm.2 Av for 1.2 GHz; 200-3000 mW/cm.2 Pk, 0.3-20 mW/cm.2 Av, and 0.1-20 mW/cm.2 CW at 1.3 GHz
SAR: not given
Exposure conditions: 30 min for pulsed 1.2 GHz; 35 min for CW 1.3 GHz
AUTHOR ABSTRACT: Since the reported alterations of permeability of the blood-brain barrier by microwave radiation have implications for safety considerations in man, studies were conducted to replicate some of the initial investigations. No transfer of parenterally-administered fluorescein across the blood-brain barrier of rats after 30 min of 1.2-GHz radiation at power densities from 2-75 mW/cm.2 was noted. Increased fluorescein uptake was seen only when the rats were made hyperthermic in a warm-air environment. Similarly, no increase of brain uptake of 14-C-mannitol using the Oldendorf dual isotope technique was seen as a result of exposure to pulsed 1.3-GHz radiation at peak power densities up to 20 mW/cm.2 or in the continuous wave mode from 0.1-50 mW/cm.2. An attempt to alter the permeability of the blood-brain barrier for serotonin with microwave radiation was unsuccessful. From these studies it would appear that the brain must be made hyperthermic for changes in permeability for the barrier induced by microwave radiation to occur.
OTHER INFORMATION: Much of this work was directed toward replicating the studies of Frey et al. (1975) and of Oscar and Hawkins (1977). To validate the detection methodology, Merritt et al. used hypertonic urea, known to alter the blood-brain barrier (BBB), as an alternative agent to RFR. In their fluorescein study, examination with ultraviolet of brain slices from RFR-exposed rats showed no evidence of BBB alteration whereas fluorescein penetration was evident for rats perfused with hypertonic urea. Similar results were seen in examination with white light of slices from rats treated with Evans blue instead of fluorescein. In addition to examining brain slices, the investigators chemically analyzed various brain regions for fluorescein content. The results for rats exposed at various power densities are presented in tabular form in the paper. Also included in the table are fluorescein analysis for

sham-irradiated rats that were heated for 30 min in a 43 deg C oven. The increase of fluorescein uptake under hyperthermic conditions, reported in the abstract, summarizes the results in this table. In the 14-C-mannitol study of the various brain regions, there were no significant differences in the Brain Uptake Index (BUI) between RFR-and sham-exposed rats, whereas BUI changes were evident for rats treated with urea instead of RFR. Also, the results (with 1.3 GHz CW RFR) showed no evidence for the existence of the power density window reported by Oscar and Hawkins.

FINAL CRITIQUE: The use of urea as a positive control (alternative agent to RFR) offers considerable weight to the negative findings by Merritt et al. on BBB alteration by RFR, especially the results of their chemical analyses of brain regions for fluorescein content and of their radioactive-tracer work. However, there remains a basic uncertainty in this and most other prior research on possible RFR-induced BBB alterations as to whether significant artifacts are introduced by the kinds of biological techniques used. As a case in point, the validity of the Oldendorf (1970) technique of injecting the dual-radiotracer mixture into a carotid rapidly as a bolus (used by Oscar and Hawkins and replicated by Merritt et al.) is questionable. Also, the effects on the overall findings of the use of anesthesia in many animal experiments are difficult to ascertain. One well known consequence of anesthetizing rats is the induction of hypothermia which could yield results that are different from those with thermonormic animals. (The decrease of fluorescein content for rats exposed to 2 mW/cm.2 relative to the sham-exposed group, as reported by Merritt et al., is perhaps a trivial example.)

REFERENCES: Frey, A. H., S. R. Feld, and B. Frey, NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP; Ann. N.Y. Acad. Sci., Vol. 247, pp. 433-439 (1975)

Oldendorf, W. H., MEASUREMENT OF BRAIN UPTAKE OF RADIOLABELED SUBSTANCES USING A TRITIATED WATER INTERNAL STANDARD, Brain Res., Vol. 24, pp. 372-376 (1970)

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Oscar, K. J. and T. D. Hawkins
MICROWAVE ALTERATION OF THE BLOOD-BRAIN BARRIER SYSTEM OF RATS
Brain Res., Vol. 126, pp. 281-293 (1977)
Study type: (5) Nervous system (blood-brain barrier);
IN-VIVO; RAT
Effect type: RFR-induced blood-brain-barrier permeability
Frequency/wavelength: 1.3 GHz
Modulation: Pulsed and CW
Power Densities: pulsed: 0.06-1.6 W/cm.2 Pk, 0.03-2 mW/cm.2 Av; CW: 0.3-3 mW/cm.2
SAR: not given
Exposure conditions: Single, 20-min exposures; pulse widths ranging from 0.5 to 20 microsec at 1000 to 5 pps.
AUTHOR ABSTRACT: Rats were exposed to 1.3 GHz microwave energy to assess the uptake of several neutral polar substances in certain areas of the brain. A quantitive, radioactive isotope method, which uses an internal standard, was employed to measure the loss of test substances to brain tissue. Single, 20 min exposure, to either pulsed or continuous wave (CW) microwave energy induced an increase in the uptake of D-mannitol at average power densities of less than 3.0 mW/cm.2. The permeability change was greatest in the medulla, followed, in decreasing order, by the cerebellum and hypothalamus, with small or negligible changes in the hippocampus and cortex. Permeability increases were observed for mannitol and inulin but not for dextran. Increased permeability was observed both immediately and 4 h after exposure, but not 24 h after exposure. After an initial rise, the permeability of cerebral vessels to saccharides decreased with increasing microwave power. Differences in the level of uptake occurred between CW energy and pulsed energy of the same average power. Microwaves of the same average power but different pulse characteristics also produced different uptake levels. Our findings suggest that microwaves induce a temporary change in the permeability for small molecular weight saccharides in the blood-brain barrier system of rats.
OTHER INFORMATION: The basic technique used to detect BBB alterations is the dual-radioactive tracer procedure developed by Oldendorf (1970) involving post-irradiation (or sham-irradiation) injection of a specified mixture of a C-14-labeled material and tritiated water into a carotid rapidly as a bolus, decapitation of the animal after 15 sec, removal of the brain, dissolving each brain region in a solubilizer, adding liquid scintillation mixture, and using a counter to determine the C-14 and H-3 radioactivities. For each specimen, the Brain Uptake Index (BUI), defined as the quotient (in percent) of C-14/H-3 in the specimen and the C-14/H-3 in the injectate, is calculated. The BUI represents the relative amount of test substance lost to the brain in a

single passage of the mixture through the microcirculation. These investigators reported the occurrence of an inverted U-shaped dependence of mannitol uptake by the medulla on average power density for both pulsed and CW RFR. The maximum BUI for CW was about 9 percent, at a power density of about 1 mW/cm.2, whereas for 0.5 microsec pulses, 1000 pps, the maximum BUI was only about 7.5 percent, at an average power density of about 0.4 mW/cm.2; higher and lower power densities in each case yielded lower BUI values. For 10 microsec pulses, 5 pps, BUI values of about 7 and 10 were obtained at average power densities of only 0.03 and 0.06 mW/cm.2, respectively.
FINAL CRITIQUE: The validity of these findings of RFR-induced BBB alterations is questionable on several grounds. Of doubtful validity are the assumptions underlying the Oldendorf methodology that tritiated water freely diffuses between the brain and its vascular system and that variations of cerebral blood flow (CBF) do not significantly affect BUI values. In the context of the latter point, Oscar et al. (1979) have found that exposure of rats to 1 and 15 mW/cm.2 average power density alters the CBF rate. Techniques that are largely independent of CBF rate, such as those subsequently developed by Rapoport et al. (1979) are being proposed as alternatives. Perhaps most important, subsequent investigators, notably Merritt et al. (1978), were unable to replicate the results of Oscar and Hawkins.
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Oscar, K. J., S. P. Gruenau, M. T. Folker, and S. I. Rapoport, LOCAL CEREBRAL BLOOD FLOW FOLLOWING MICROWAVE EXPOSURE, Presented at the Bioelectromagnetics Symposium, U. of Washington, Seattle, WA, 18-22 June 1979
0048-6604/79/1112-S051, Rapoport S. I., K. Ohno, W. R. Fredericks, and K. D. Pettigrew, A QUANTITIVE METHOD FOR MEASURING ALTERED CEREBROVASCULAR PERMEABILITY, Radio Sci., Vol. 14, No. 6S, pp. 345-348 (1979)

Oscar, K. J., S. P. Gruenau, M. . Fotker, and S. I. Rapoport
LOCAL CEREBRAL BLOOD FLOW FOLLOWING MICROWAVE EXPOSURE
Presented at the Bioelectromagnetics Symposium, U. of Washington, Seattle WA, 18- Jun 79
Study type: 5: Nervous system (blood-brain barrier); (9) Biochemical/physiological; in vivo; RAT
Effect type: RFR-induced change in local cerebral blood flow
Frequency/wavelength: 2.8 GHz
Modulation: 2 microsec pulses, 500 pps
Power Densities: 1.15 W/cm.2 [illegible] 1.15 mW/cm.2 Av
SAR: not given
Exposure conditions: 30 min exposures in anechoic chamber maintained at 23 deg C
AUTHOR ABSTRACT: Local cerebral blood flow was measured in several different rat brain structures with a radioactive iodoantipyrine technique. Exposure to pulsed microwaves of either 1 or 15 mW/cm.2 power density increased the local cerebral blood flow in several different brain regions. The iodoantipyrine technique allowed the use of conscious rats for both the microwave exposure and the regional determination of brain blood flow. Local cerebral blood flow increases of 10 to 144 percent occurred in [illegible] 28 brain regions sampled in both the 1 and 15 mW/cm.2 [illegible] exposed rats. The largest statistically significant increases occurred in the pineal, hypothalamus, and temporal cortex in the 1 mW/cm.2 exposed rats and in the pineal, visual cortex, inferior colliculus, and medial geniculate in the 15 mW/cm.2 exposed rats. Our experiments measuring the increased brain flow, along with the Wit[illegible] (Brain Res. in press) showing increased [illegible], confirm that low-power microwaves can cause [illegible] in rat brains.
OTHER INFORMATION: [illegible] iodoantipyrine in isotonic saline was infused [illegible] in within 5 min after RFR or sham-exposure. [illegible] blood collected during infusion were [illegible] vials. After 50 sec of infusion, [illegible] brain regions were dissected out [illegible] on vials, weighed, and solubilized. [illegible] was added to each vial and the samples [illegible] counting techniques. Local blood flows were calculated from the radioactivity [illegible] Sokoloff (1960) equation. In addition, the [illegible] due to RFR exposure, the authors report [illegible] indicate higher blood flow rate from exposure [illegible] from 15 mW/cm.2, an indication of the possible [illegible] of a power density window.
FINAL CONCLUSIONS: The [illegible] evidence that RFR at the average [illegible] investigation can alter cerebral blood flow [illegible] because in an earlier paper (Oscar and Hawkins, [illegible] ences in Brain Uptake

Index (BUI) of C-14 labeled mannitol and inulin between RFR-exposed and control rats were ascribed to RFR-induced alterations of the blood-brain barrier without recognition that such differences in BUI could be due to RFR-induced cerebral blood flow changes. The data indicating the possible existence of a power-density window are too few to permit evaluation of the validity of this finding. Additional work covering a broader range of average power densities as well as intermediate values would be necessary to confirm the existence and limits of such a power-density window for alterations of cerebral blood flow rates.

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Rapoport, S. I., K. Ohno, W. R. Fredericks, and K. D. Pettigrew
A QUANTITATIVE METHOD FOR MEASURING ALTERED CEREBROVASCULAR PERMEABILITY
0048-6604/79/1112-S051, Radio Sci., Vol. 14, No 6S, pp. 345-348 (1979)
Study type: (5) Nervous system (blood-brain barrier); IN-VIVO; RAT
Effect type: blood-brain barrier methodology
Frequency/wavelength: None
Modulation: None
Power Densities: None
SAR: None
Exposure conditions: Not applicable
AUTHOR ABSTRACT: Cerebrovascular permeability to C-14-sucrose was measured independently of cerebral blood flow in the rat, following unilateral osmotic opening of the blood-brain barrier by hypertonic arabinose solution. An increase in regional permeability to C-14-sucrose was correlated with the extent of brain staining by intravascular Evans blue-albumin, a visual barrier tracer. To obtain the product of capillary permeability and surface area, C-14-sucrose was injected intravenously, the arterial plasma concentration curve was determined and integrated over a 10-min period, and brain parenchymal concentration was calculated after subtracting vascular radioactivity from net tissue radioactivity. Conditions were chosen so that a simple diffusion equation could be applied to exchange between plasma and brain compartments, in the absence of back flux from brain. The method should be of use for studying effects of microwaves on the cerebral vasculature.
OTHER INFORMATION: Because of blood flow, the intravascular concentration, in each brain region, of radioactive material injected into an animal varies with time. A major point of the technique described is to measure the radioactivity of blood samples drawn at 1-min intervals over a given time period (e.g., 10 min) after injection of the material, followed by integration of the resulting curve over the specified time period. The numerical value obtained is effectively the mean intravascular concentration for that time period, at the end of which the animal is decapitated and the concentration of radioactivity in each brain region is determined. Based on the assumptions that the quantity of radioactive material that diffuses into the parenchyma of each region during that time period is proportional to the mean intravascular concentration, and that back diffusion is negligible, the authors use the radioactivity data from each brain region to calculate the product of cerebrovascular permeability (P) and capillary surface area (A) in each brain region in a manner that is not

confounded by variations of cerebral blood flow rate. The authors indicate a hundredfold higher sensitivity in measuring PA for C-14-sucrose than with the Brain Uptake Index Technique or the Indicator Dilution Technique.
FINAL CRITIQUE: This technique represents a significant advance over the other radioactive-tracer techniques used previously to investigate possible RFR-induced alterations of the BBB, notably those based on dual-tracer analyses leading to calculations of Brain Uptake Index as a measure of BBB permeability. However, the new technique involves the use of anesthesia and injection of the radioactively tagged tracer as a bolus, with the possibility of artifact introduction (as with the earlier techniques). It should also be noted that this paper contains results obtained only by the use of arabinose as the BBB-alteration agent (i.e., none with RFR).
REFERENCES: None

Spackman, D. H., V. Riley, A. W. Guy, and C.-K. Chou
STUDIES OF RF RADIATION EFFECTS ON BLOOD-BRAIN BARRIER PERMEABILITY USING FLUORESCEIN AND AMINO ACIDS
Presented at the Open Symposium on Biological Effects of Electromagnetic Waves, Helsinki, Finland, 1-8 August 1978
Study type: (5) Nervous System (blood-brain barrier);
IN-VIVO; MOUSE
Effect type: RFR-induced blood-brain barrier permeability
Frequency/wavelength: 918 MHz
Modulation: pulsed and CW
Power Densities: pulsed: 2.5 and 33 mW/cm.2 av (.001 duty);
CW: 1.2 mW/cm.
SAR: not indicated
Exposure conditions: [illegible] groups of four to circularly polarized [illegible] min. Pulsed RFR was 10 microsec, 100 pps.
AUTHOR ABSTRACT: Previous studies in rats, by several investigators, showed an increased permeability of the blood-brain barrier (BBB) [illegible] test substances following RF radiation [illegible]. It was further reported that pulsed [illegible] was significantly more effective than [illegible] at comparable power levels for [illegible], we repeated in mice using fluorescein (FSN) [illegible] amino acids as test substances. [illegible] ation of the test mixture, [illegible] by retro-orbital bleeding and the [illegible] carbon dioxide. The vascular system [illegible] with cold saline and the brain removed. [illegible] extracts of plasma and of brain homogenates [illegible] FSN with a spectrofluorometer [illegible] with an automatic amino acid analyzer. [illegible] of FSN and amino acids were then compared [illegible] concentrations in normal control [illegible] group, four mice were [illegible] holder. The holder was [illegible] circularly polarized waveguide [illegible]. Separate groups were in turn exposed [illegible] 1000 pps, 10 microsec/pulse RF [illegible] GHz for 30 min. Following [illegible] sequence was performed [illegible] average power densities of 2.5 and 33 [illegible] mode were tested; a CW exposure [illegible] system. Using the objective [illegible] bed, we could not detect any [illegible] 33 irradiated animals as compared [illegible]
OTHER INFORMATION: [illegible] was a mixture of [illegible] physiological amino acids. [illegible] were taken by

retro-orbital bleeding. Plasma and brain tissue samples were deproteinized, homogenized, and clarified by high-speed centrifugation. The extracts were then analyzed for both FCN and amino acid content, using a spectrofluorometer for the former and an amino acid analyzer for the latter. The specific concentration, defined as the ratio of brain concentration to plasma concentration, was calculated for each test constituent.
INITIAL CRITIQUE: The sensitivity of the analyses for FCN and the various amino acids is noteworthy, and the finding of no RFR-induced alteration of the BBB appears valid. However, in this brief paper the authors do not discuss the statistical treatment of the data. Presumably, they intend to publish the paper, in which case it will be reviewed again.
REFERENCES: none

(5) NERVOUS SYSTEM (Calcium Efflux)

List of Analyses

Bawin, S. M. and W. R. Adey
SENSITIVITY OF CALCIUM BINDING IN CEREBRAL TISSUE TO WEAK ENVIRONMENTAL FIELDS OSCILLATING AT LOW FREQUENCY
Proc. Nat. Acad. Sci., Vol. 73, No. 6, pp. 1999-2003 (1976)

Bawin, S. M., L. K. Kaczmarek, and W. R. Adey
EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM
Ann. N.Y. Acad. Sci., Vol. 247, pp. 74-81 (1975)

Blackman, C. F., J. A. Elder, C. M. Weil, S. G. Benane, C. C. Eichinger, and D. E. House
INDUCTION OF CALCIUM-ION EFFLUX FROM BRAIN TISSUE BY RADIO-FREQUENCY RADIATION: EFFECTS OF MODULATION FREQUENCY AND FIELD STRENGTH
0048-6604/79/1112-S014, Radio Sci., Vol. 14, No. 6S, pp. 93-98 (1979)

Sheppard, A. R., S. M. Bawin, and W. R. Adey
LEVELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MODULATED VHF AND UHF FIELDS
0048-6604/79/1112-S021, Radio Sci., Vol. 14, No. 6S, pp. 141-145 (1979)

Analyses under

(5) NERVOUS SYSTEM (Calcium Efflux)

rather than increases of calcium efflux, with threshold fields of 10 and 56 V/m for the chick and rat, respectively. Moreover, the data indicate the existence of an amplitude "window", i.e. for the chick embryo, statistically significant responses were seen for 10 and 56 V/m (with 6 and 16 Hz) but not for 3 and 100 V/m. In presenting the results, the authors state the following: "Our pilot studies with radio frequency fields demonstrated that stimulated counts more than 40% above or below the mean of any set of 10 samples can be discarded as spurious due to improper mental errors in washing the tissue after incubation or in collecting the supernatant following the addition of the precipitating agent. Two statistical criteria applied to each set of data confirmed our previous observations. Extreme counts in any set more than 1.5 standard deviations away from the mean also satisfied the probability (P = 0.1 to 0.01) in a statistical method based on the range of values (maximum minus minimum) of extreme ranking observations; Dixon, 1951). Therefore, such extreme values were eliminated from the sera (fields as well as controls) before final analysis of the data." Regarding the magnitudes of the induced internal field, they state that a 10 V/m, 7 Hz field in air induces an average gradient of less than 0.1 microvolt/cm in a [illegible]. Also, citing work by Miller et al. (1974). [illegible] the possible coupling of the [illegible] to be involved. Instead, [illegible] capable of rectifying the [illegible] within those for the [illegible] exist in the [illegible] of calcium efflux occur [illegible] calculated 147 MHz RFR is [illegible] on possible [illegible] including the triggering [illegible] membrane surface, but [illegible] the numerical [illegible] a posteriori [illegible] or experimental error [illegible] acceptable, and [illegible], in a recent [illegible] that "With [illegible] slow latency in [illegible], and [illegible] with the [illegible] the occurrence [illegible] no differences were [illegible] found at the P less than [illegible] once estimated by the [illegible] estimated magnitudes of the [illegible] understand the [illegible] rhesus monkey head to

the brain preparation [illegible] experiments on the effect with modulated 147 MHz has been confirmed by Bawin et al. (1979). However, it is [illegible] to assess the significance of this [illegible] with [illegible] possible in-vivo effects on humans.

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EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM
Ann. N. Y. Acad. Sci., Vol. 247, pp. 74-81 (1975)
Study type: (5) Nervous system (calcium efflux), (11) Mechanisms of interaction; IN-VITRO; CHICK
Effect type: Alterations of calcium binding to cell membranes in the neonate chick brain by modulated RFR
Frequency/wavelength: 147 MHz
Modulation: Discrete frequencies between 0 and 35 Hz at 80-90% modulation
Power Densities: 1-2 mW/cm.2 Av
SAR: Not determined
Exposure conditions: After incubating in solution containing Ca-45 and washing in nonradioactive solution, half brains were immersed in physiological solution while being exposed for 20 min to RFR. The corresponding half-brain of each chick served as control.
REVIEWER SUMMARY: Five hundred neonatal chicks were used. After decapitation, the brains were dissected out and each hemisphere was incubated in 1 ml of physiologic medium together with 0.2 ml of saline containing 0.2 microcurie of Ca-45 ions. After incubation, the samples were washed 3 times with nonradioactive solution, and were immersed in 1 ml of physiologic medium and exposed or not exposed to RFR for 20 min. Aliquots of 0.2 ml were then assayed for radioactivity by liquid scintillation counting. The radioactivities (counts per minute) of the samples were normalized to the mean values for control samples. Unmodulated 147-MHz RFR and fields modulated at 0.5, 3, 6, 9, and 16 Hz showed a progressive increase in the normalized counts (calcium efflux); of these results, those for 0, 0.5, and 3 Hz were not statistically significant; those for 6 and 9 Hz were significant at the 5% level, and those for 11 and 16 Hz were significant at the 1% level, with the highest efflux at 16 Hz. RFR modulated at 20, 25, and 35 Hz yielded progressive diminution of efflux from the value at 16 Hz, with the result for 20 Hz being significant at the 5% level and those for 25 and 35 Hz being insignificant. The effect of RFR modulated at 0.5 and 16 Hz on brains poisoned with cyanide after incubation were also studied. The results of these two modulation frequencies were the same as those for samples not given the cyanide treatment. Calcium efflux from skeletal muscular tissue of chicks was studied by the same methodology for 5 and 16 Hz modulation. The results exhibited much greater variability than those for brain tissue, but there were no statistically significant differences between exposed and unexposed samples.
OTHER INFORMATION: This paper is one of the first on this subject by these investigators. Later papers review the results of this study and present results for unmodulated RFR

in the sub-extremely-low-frequency (sub-ELF) [illegible] for 450 MHz modulated at 16 Hz (e.g., Bawin and Adey, [illegible] and 1977). Blackman et al. (1979) report experiments [illegible] some of the results for 147 MHz modulated at frequ[illegible] between 3 and 30 Hz. Sheppard et al. (1979) discuss [illegible] 450 MHz results and present a model for the effect.

FINAL CRITIQUE: The results of this investiga[illegible] constitute evidence for the existence of a quite subtle [illegible] effect. The absence of the effect for unmodulated RFR and [illegible] modulation frequencies outside the range reported is an [illegible] that heating of the preparation by the RFR is unli[illegible] to be involved. Rather, some nonlinear mechanism [illegible] exist in the preparation that is capable of responding [illegible] according to one polarity of the modulation envelope. Such [illegible] mechanism would also have to have a time constant compa[illegible] to that for 16 Hz, at which the effect is near maximum. [illegible] authors speculate that such slow undulations of the [illegible] near electric field could affect the binding of [illegible] to the neuronal membrane, and that a small displace[illegible] of calcium ions would result in cooperative interaction [illegible] on modified adjacent binding sites, thus producing propaga[illegible] and amplification of local electrical events. It [illegible] difficult to ascertain the significance of this in-vi[illegible] to [illegible] to check brains with regard to possible in-vivo effect[illegible] humans.

REFERENCES: Bawin, S. M. and W. R. Ade[illegible] Effects of CALCIUM BINDING IN CEREBRAL TISSUE TO WEAK EN[illegible] RENTAL ELECTRIC FIELDS OSCILLATING AT LOW FREQUENCY, Proc. Nat. Acad. Sci., Vol. 73, No. 6, pp. [illegible] (1976)
Bawin, S. M. and W. R. Adey, CALCIUM BINDING [illegible] BRAL TISSUE, in D. G. Hazzard (ed.), SYMPOSIUM ON [illegible] ONAL EFFECTS AND MEASUREMENT OF RADIO FREQUENCY/MICROWAVES, U.S. Dept. of Health, Education, and Welfare, Washington, D[illegible] HEW Publications (FDA) 77-8026 (1977)
0048-6604/79/1112-S014, Blackman, C. F., J. A. [illegible], C. M. Weil, S. G. Benane, D. C. Eichinger [illegible] House, INDUCTION OF CALCIUM-ION EFFLUX FROM BRAIN [illegible] BY RADIO-FREQUENCY RADIATION: EFFECTS OF MODULA[illegible] FREQUENCY AND FIELD STRENGTH, Radio Sci., Vol. 14, No. 6S, [illegible] 98 (1979)
0048-6604/79/1112-S021, Sheppard, A. R., S. M. [illegible] and W. R. Adey, MODELS OF LONG-RANGE ORDER IN [illegible] MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MO[illegible] ED VHF AND UHF FIELDS, Radio Sci., Vol. 14, No. 6S, pp. [illegible] (1979)

Blackman, C. F., J. A. Elder, C. M. Weil, S. G. Benane, D. C. Eichinger, and D. E. House
INDUCTION OF CALCIUM-ION EFFLUX FROM BRAIN TISSUE BY RADIO-FREQUENCY RADIATION: EFFECTS OF MODULATION FREQUENCY AND FIELD STRENGTH
0048-6604/79/1112-S014, Radio Sci., Vol. 14, No. 6S, pp. 93-98 (1979)
Study type: (5) Nervous system (calcium efflux); IN-VITRO; CHICK
Effect type: Alterations of calcium binding to cell membranes in chick brains
Frequency/wavelength: 147 MHz
Modulation: CW and 3-30 Hz (at less than 95%)
Power Densities: 0-2.0 mW/cm.2
SAR: Less than 0.075 mW/g
Exposure conditions: After each half-brain was weighed, it was incubated in physiological medium containing Ca-45, washed in nonradioactive medium, and exposed for 20 min in a Crawford cell while immersed in physiological medium
AUTHOR ABSTRACT: Bawin and her coworkers have reported changes in binding of calcium after exposure of avian brain tissue to nonionizing electromagnetic radiation. Because calcium is intimately involved in the electrical activity of the brain, their results reveal a heretofore unrecognized potential for nonionizing radio-frequency radiation to affect biological function. We have verified and extended their findings. The forebrains of newly hatched chickens, separated at the midline to provide treatment-control pairs, were labeled in-vitro with radioactive calcium. Samples of tissue were exposed for 20 minutes in a Crawford irradiation chamber to 147-MHz radiation, which was amplitude modulated sinusoidally at selected frequencies between 3 and 30 Hz. Power densities of incident radiation ranged between 0.5 and 2 mW/cm.2. Compared with nonirradiated samples, a statistically significant increase in efflux of calcium ions (P less than 0.01) was observed in irradiated samples at a modulation frequency of 16 Hz and at a power density of 0.75 mW/cm.2. Our data confirm the existence of the frequency "window" reported by Bawin et al., as well as a narrow power-density "window" within which efflux of calcium ions is enhanced.
OTHER INFORMATION: This research was directed toward reproducing the calcium-efflux phenomenon in chick brains reported by Bawin et al. (1975) for 147 MHz RFR modulated at sub-ELF frequencies. After decapitation of each chick, its forebrain was removed and divided at the midline, and each half was weighed. Each specimen was then immersed in 1 ml of physiological medium labeled with Ca-45 and agitated for 30 min at 37 deg C. The radioactive medium was aspirated and each half brain was rinsed successively in two 250-ml volumes of

nonradioactive medium and bathed in 1 ml of medium during exposure or sham exposure. Half brains were exposed for 20 min each in two series, with the corresponding halves serving as controls. In one series, the modulation frequency was 16 Hz and the power density was 0, 0.5, 0.75, 1.0, 1.5, or 2.0 mW/cm.2; in the other, the power density was 0.75 mW/cm.2 and the modulation frequency was 0, 3, 9, 16, or 30 Hz. Following exposure or sham exposure, 0.2-ml aliquots of bathing medium were assayed or radioactivity by liquid scintillation counting. The counts per min (CPM) value for each specimen was divided by the weight of the specimen and the difference in value for an exposed half brain and its corresponding control half was treated as the variable for statistical analysis. The results for constant power density (0.75 mW/cm.2) showed that the mean difference at 16 Hz is significantly higher (P less than 5%) than the mean at 30 Hz and the mean for the sham-exposed specimens. Increases were noted for the groups exposed to unmodulated, 3-Hz, and 9-Hz modulated RFR, but these increases were not statistically significant. The results for varied power density with 16-Hz modulation showed that the mean difference for 0.75 mW/cm.2 was significantly higher (P less than 1%) than the means for sham exposure and the other four power densities. Also, the means for the latter differed little from the mean for sham exposure. The authors state that: "These results indicate a maximal power-density effect at 0.75 mW/cm.2 and no enhancement at levels plus or minus 0.25 mW/cm.2 of this value. The narrow width of this window was not observed in the preliminary study in which intermediate values for enhanced efflux were found at 0.5 and 1.0 mW/cm.2."
FINAL CRITIQUE: The results of this research represent experimental confirmation for the existence of the calcium efflux phenomenon in excised chick brains, at least for modulated 147 MHz RFR. The power density window described in this paper appears to be narrower than the windows found by Bawin and coworkers for modulated 450 MHz RFR (Sheppard et al., 1979) and sinusoidal sub-ELF fields (Bawin et al., 1979). It is difficult to ascertain the significance of this in-vitro phenomenon with regard to possible in-vivo effects in humans.
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0048-6604/79/1112-S021, Sheppard, A. R., S. M. Bawin, and W. R. Adey, MODELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MODULATED VHF AND UHF FIELDS, Radio Sci., Vol. 14, No. 6S, pp. 141-145 (1979)

Sheppard, A. R., S. M. Bawin, and W. R. Adey
MODELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MODULATED VHF AND UHF FIELDS
0048-6604/79/1112-S021, Radio Sci., Vol. 14, No. 6S, pp. 141-145 1979)
Study type: (5) Nervous system (calcium efflux), (11) Mechanisms of interaction; IN-VITRO; CHICK
Effect type: Alterations of calcium binding to cell membranes in chick brains
Frequency/wavelength: 450 MHz
Modulation: 90% at 16 Hz
Power Densities: 0.5 to 5 mW/cm.2
SAR: Unknown
Exposure conditions: After incubation in physiological solution containing Ca-45 and washing in nonradioactive solution, brain halves were immersed in fresh physiological solution while being exposed for 20 min.
AUTHOR ABSTRACT: Weak RF fields (450 MHz) that were sinusoidally modulated at 16 Hz increased the efflux of calcium ion from freshly isolated chick brain. The data demonstrate upper and lower bounds for power levels of incident fields at which the change of efflux is observed. These bounds, greater than 0.05 mW/cm.2 and less than 2.0 mW/cm.2, constitute an amplitude window for the calcium-efflux effect, which is also characterized by a frequency window demonstrated in previous experiments. The mechanisms by which weak low-frequency fields -- or weak high-frequency fields modulated at sub-ELF rates -- interact with biological tissue derive from the properties of the biological components of neuronal membrane and from the unique dielectric properties of biological tissues in fields that oscillate at brain-wave frequencies.
OTHER INFORMATION: A total of 190 chick brains was used in this study. After the cerebrum of each chick was removed, separated into hemispheres, and weighed, the specimens were incubated at 36 deg C for 30 min in a physiological solution containing Ca-45 and rinsed 3 times in nonradioactive solution. Groups of 5 half brains, each in 1 ml of physiological solution, were exposed for 20 min. After exposure, 0.2-ml aliquots of the solution were assayed for radioactivity by liquid scintillation counting. In addition, the half brains were dissolved overnight and assayed for radioactivity. The corresponding half brains of each group served as controls; they were not exposed but were otherwise similarly treated together with the exposed specimens. The authors indicate that it was not necessary to discard any data points (as was done with extreme values in their previous studies; see Bawin and Adey, 1976). Modulation of only 16 Hz was used, this being the frequency for maximum effect in prior studies with 147 MHz (Bawin et al., 1975). Incident average power densities of

0.05, 0.10, 1.0, 2.0, and 5.0 mW/cm.2 were used, and the mean radioactivity values for each exposure group were normalized to the mean values for the corresponding control groups. The assays of the bathing solutions indicate a statistically significant (at less than the 5% level) increase in calcium efflux for 0.10 and 1.0 mW/cm.2 and no change for 2.0 or 5.0 mW/cm.2. There was a decrease for 0.05 mW/cm.2 but the change was not statistically significant. The assays of the dissolved brain specimens indicated that the greater proportion of Ca-45 remains in the tissue and that there were no statistically significant differences in these assays between exposed and control groups. The authors propose a model for the interaction of weak electric fields with neuronal membranes, which describes amplification of weak signals by the cooperative behavior of glycoprotein-bound ions under the influence of a field enhanced by the polarization of surrounding unbound ions. They suggest that the presumed field-triggered cooperative behavior of the bound ions could change the calcium binding and give rise to the effects found. A recent review of the work at modulated 147 MHz and 450 MHz RFR and at sub-ELF fields is given by Adey (1980).

FINAL CRITIQUE: The occurrence of a field-induced calcium efflux, confirmation of which was reported by Blackman et al. (1979) for modulated 147 MHz RFR, requires that some nonlinear mechanism exist in the preparations that is capable of recovering and/or responding to one polarity of the modulation envelope. Such a mechanism would also have to have a time constant corresponding approximately to that for 16 Hz. The paper speculates about such mechanisms, and states that: "Adey has suggested that the sub-ELF envelope impressed on the RF carrier is detected at the polyanionic surface due to a strong asymmetry in charge distribution with respect to that surface. The charge asymmetry at the borders of glycoprotein-dense regions may allow demodulation much as in the case of a semiconductor diode but further details of the mechanism and its coupling to the cooperative system have not been developed." Among the observations not yet accounted for are why increased calcium efflux occurs for modulated 147 and 450 MHz RFR and decreased efflux for sinusoidal sub-ELF fields, and why the phenomenon only occurs within an amplitude or power-density window. In addition, it is difficult to ascertain the significance of this in-vitro effect in chick (and cat) brains with regard to possible in-vivo effects in humans.

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CEREBRAL TISSUE TO WEAK ENVIRONMENTAL ELECTRIC FIELDS OSCILLATING AT LOW FREQUENCY, Proc. Nat. Acad. Sci., Vol. 73, No. 6, pp. 1999-2003 (1976)
Bawin, S. M., L. K. Kaczmarek, and W. R. Adey, EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM, Ann. N. Y. Acad. Sci., Vol. 247, pp. 74-81 (1975)
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(5) NERVOUS SYSTEMS (EEG and EP)

List of Analyses

Chou, C.-K., A. W. Guy, J. B. McDougall, and L.-F. Han
EFFECTS OF CONTINUOUS AND PULSED CHRONIC MICROWAVE EXPOSURE ON RABBITS
In ABSTRACTS OF OPEN SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, Helsinki, Finland (1978)

Analyses under

(5) NERVOUS SYSTEM (EEG and EP)

Chou, C.-K., A. W. Guy, J. B. McDougall, and L.-F. Han
EFFECTS OF CONTINUOUS AND PULSED CHRONIC MICROWAVE EXPOSURE ON RABBITS
In ABSTRACTS OF OPEN SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, Helsinki, Finland (1978)
Study type: (5) Nervous system (EEG and EP), (9) Biochemical/physiological, (4) Ocular, (18) Drug interactions, (6) Behavioral; IN-VIVO; RABBIT
Effect type: EEG & EP; body weights; blood chemistry; ocular; drug-behavioral; histopathology
Frequency/wavelength: 2.45 GHz
Modulation: CW and pulsed
Power densities: 1.5 W/cm.2 Pk; 1.5 mW/cm.2 Av
SAR: 1.64 W/kg Pk in head; 2.1 W/kg Pk in back
Exposure conditions: 2 hrs/day for 3 mos
AUTHOR ABSTRACT: Eighteen young adult New Zealand rabbits (nine males, nine females) were equally divided into three groups. One group was exposed to CW 2450 MHz fields at an incident power density of 1.5 mW/cm.2 for two hours daily for three months. Another group was exposed to pulsed fields with pulses 10 microseconds duration occurring 100 times per second. The third group was sham exposed. Each rabbit was placed in a plexiglass cage and exposed in a miniature plane-wave exposure chamber. An S-band horn was mounted 1 m above the animal. Thermographic data showed a peak SAR of 1.64 W/kg in the head and 2.1 W/kg in the back. Body weights were measured every other day. EEG and evoked potentials were recorded weekly via implanted carbon-loaded Teflon electrodes. Blood samples were taken monthly for hematological, chemical, and morphological studies. Eyes were examined for cataract formation. At the end of this study, apomorphine was injected into the animals to study the differences in induced behavioral excitation and hyperthermia. Finally, pathological examinations on many tissues and organs were performed. Statistically, there were no significant differences in measured parameters observed between the exposed and sham animals. The large variations in EEG and evoked potentials made the comparison difficult. Preliminary results on drug-induced behavioral study showed some indication of differences in exposed animals.
OTHER INFORMATION: EEG varied widely from animal to animal and for the same animal at different times. The histopathology studies were done only on animals that survived the drug-injection studies.
INITIAL CRITIQUE: There were no statistically significant differences among the CW, pulsed, and sham-exposed groups in body-weight gain per day, EEG, visually and auditory evoked potentials, blood chemistry, or histopathology. Also, no cataracts developed in any animal. However, Shandala et al. (1976) had reported that the EEG frequency was stable in

control animals, whereas Chou et al. found variability for sham-exposed as well as RFR-exposed animals. Also, the variability of the visually evoked potentials found by Chou et al. was contrary to the findings of Baranski and Edelwejn (1974). This initial study of the synergistic effects of RFR and apomorphine-induced hyperthermia and related hyperactivity was not as successful as hoped because the animals used were found to be far more sensitive to the doses of apomorphine than reported in the literature, and a number of the animals died shortly after injection. The findings of Chou et al. indicate that the RFR-exposed animals are more sensitive to apomorphine than the sham-exposed animals, with higher sensitivity to those exposed to pulsed RFR than to CW. However, because of the small numbers of animals in this part of the study, the validity of this finding is difficult to assess. A larger study is necessary.

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Shandala, M. G. et al., STUDY OF THE EFFECTS OF NON-IONIZING MICROWAVE RADIATION ON THE CENTRAL NERVOUS SYSTEM AND BEHAVIORAL RESPONSES, First Report on Topic 4.1 of the US/USSR Cooperative Program, D. McRee (Coordinator), NIEHS, Research Triangle Park, NC (1976)

(6) BEHAVIORAL

List of Analyses

Chou, C.-K., A. W. Guy, J. B. McDougall, and L.-F. Han
EFFECTS OF CONTINUOUS AND PULSED CHRONIC MICROWAVE EXPOSURE ON RABBITS
In ABSTRACTS OF OPEN SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, Helsinki, Finland (1978) (See "Nervous System (EEG and EP)" for analysis.)

Frey, A. H., S. R. Feld, and B. Frey
NEURAL FUNCTION AND BEHAVIOR: DEFINING THE RELATIONSHIP
Ann. N.Y. Acad. Sci., Vol. 247, pp. 433-439 (1975) (See "Nervous System (Blood-Brain Barrier)" for analysis.)

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHz RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS OF HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 52-57 (1974) (See "Epidemiologic" for analysis.)

Klimkova-Deutschova, E.
NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 268-272 (1974) (See "Epidemiologic" for analysis.)

Pazderova, J.
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)
Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, pp. 265-271 (1971). English translation: JPRS No. UDC 616-001.228.1-057-07 (1971) (See "Epidemiologic" for analysis.)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

(7) ENDOCRINOLOGICAL

List of Analyses

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

(8) IMMUNOLOGICAL

List of Analyses

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHz RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 52-57 (1974) (See "Epidemiologic" for analysis.)

Lilienfeld, A. M., J. Tonascia, S. Tonascia, C. H. Libauer, G. M. Cauthen, J. A. Markowitz, and S. Weida
FOREIGN SERVICE HEALTH STATUS STUDY: EVALUATION OF HEALTH STATUS OF FOREIGN SERVICE AND OTHER EMPLOYEES FROM SELECTED EASTERN EUROPEAN POSTS
Final Report, July 31, 1978, Contract No. 6025-619073, Dept. of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, MD (1978) (See "Epidemiologic" for analysis.)

(9) BIOCHEMICAL/PHYSIOLOGICAL

List of Analyses

Chou, C.-K., A. W. Guy, J. B. McDougall, and L.-F. Han
EFFECTS OF CONTINUOUS AND PULSED CHRONIC MICROWAVE EXPOSURE ON RABBITS
In ABSTRACTS OF OPEN SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, Helsinki, Finland (1978) (See "Nervous System (EEG and EP)" for analysis.)

Kalyada, T. V., P. P. Fukalova, and N. N. Goncharova
BIOLOGIC EFFECTS OF RADIATION IN THE 30-300 MHz RANGE
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 52-57 (1974) (See "Epidemiologic" for analysis.)

Klimkova-Deutschova, E.
NEUROLOGIC FINDINGS IN PERSONS EXPOSED TO MICROWAVES
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 268-272 (1974) (See "Epidemiologic" for analysis.)

Lilienfeld, A. M., J. Tonascia, S. Tonascia, C. H. Libauer, G. M. Cauthen, J. A. Markowitz, and S. Weida
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Final Report, July 31, 1978, Contract No. 6025-619073, Dept. of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, MD (1978) (See "Epidemiologic" for analysis.)

Oscar, K. J., S. P. Gruenau, M. T. Folker, and S. I. Rapoport
LOCAL CEREBRAL BLOOD FLOW FOLLOWING MICROWAVE EXPOSURE
Presented at the Bioelectromagnetics Symposium, U. of Washington, Seattle, WA, 18-22 June 1979 (See "Nervous System (Blood-Brain Barrier)" for analysis.)

Pazderova, J.
WORKERS' STATE OF HEALTH UNDER LONG-TERM EXPOSURE TO ELECTROMAGNETIC RADIATION IN THE VHF BAND (30-300 MHz)
Pracovni Lekarstvi (in Czech), Vol. 23, No. 8, pp. 265-271 (1971). English translation: JPRS No. UDC 616-001.228.1-057-07 (1971) (See "Epidemiologic" for analysis.)

(9) BIOCHEMICAL/PHYSIOLOGICAL

List of Analyses (continued)

Pazderova, J., J. Pickova, and V. Bryndova
BLOOD PROTEINS IN PERSONNEL OF TELEVISION AND RADIO TRANSMITTING STATIONS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 281-288 (1974) (See "Epidemiologic" for analysis.)

Robinette, C. D. and C. Silverman
CAUSES OF DEATH FOLLOWING OCCUPATIONAL EXPOSURE TO MICROWAVE RADIATION (RADAR) 1950-1974
In D. G. Hazzard (Ed.), SYMPOSIUM ON BIOLOGICAL EFFECTS AND MEASUREMENT OF RADIOFREQUENCY/MICROWAVES, Dept. of Health, Education, and Welfare, Washington, D. C., HEW Publication No. (FDA) 77-8026 (1977) (See "Epidemiologic" for analysis.)

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

Siekierzynski, M.
A STUDY OF THE HEALTH STATUS OF MICROWAVE WORKERS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 273-280 (1974) (See "Epidemiologic" for analysis.)

(11) MECHANISMS OF INTERACTION

List of Analyses

Bawin, S. M. and W. R. Adey
SENSITIVITY OF CALCIUM BINDING IN CEREBRAL TISSUE TO WEAK ENVIRONMENTAL FIELDS OSCILLATING AT LOW FREQUENCY
Proc. Nat. Acad. Sci., Vol. 73, No. 6, pp. 1999-2003 (1976)
(See "Nervous System (Calcium efflux)" for analysis.)

Bawin, S. M.,L. K. Kaczmarek, and W. R. Adey
EFFECTS OF MODULATED VHF FIELDS ON THE CENTRAL NERVOUS SYSTEM
Ann. N.Y. Acad. Sci., Vol. 247, pp. 74-81 (1975) (See "Nervous System (Calcium efflux)" for analysis.)

Sheppard, A. R., S. M. Bawin, and W. R. Adey
MODELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MODULATED VHF AND UHF FIELDS
0048-6604/79/1112-S021, Radio Sci., Vol. 14, No.6S,
pp. 141-145 (1979) (See "Nervous System (Calcium efflux)" for analysis.)

(14) REVIEW

List of Analyses

Sadchikova, M. N.
CLINICAL MANIFESTATIONS OF REACTIONS TO MICROWAVE IRRADIATION IN VARIOUS OCCUPATIONAL GROUPS
In P. Czerski et al. (eds.), BIOLOGIC EFFECTS AND HEALTH HAZARDS OF MICROWAVE RADIATION, Polish Medical Publishers, Warsaw, pp. 261-267 (1974) (See "Epidemiologic" for analysis.)

(16) PHYSICAL METHODS/DOSIMETRY

List of Analyses

Hagmann, M. J. and O. P. Gandhi
NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION IN MODELS OF MAN WITH GROUNDING AND REFLECTOR EFFECTS
0048-6604/79/1112-S005, Radio Sci., Vol. 14, No. 6S, pp. 23-29 (1979)

Hagmann, M. J., O. P. Gandhi, and C. H. Durney
NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION FOR REALISTIC MODEL OF MAN
0018-9480/79/0900-0804, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, 804-809 (1979)

Hagmann, M. J., O. P. Gandhi, J. A. D'Andrea, and I. Chatterjee
HEAD RESONANCE: NUMERICAL SOLUTION AND EXPERIMENTAL RESULTS
0018-9480/79/0900-0809, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 809-813 (1979)

Kritikos, H. N. and H. P Schwan
FORMATION OF HOT SPOTS IN MULTILAYER SPHERES
Int. J. Radiat. Biol. Exp., Vol. 22, pp. 168-172 (1976)

[illegible] and H. P. Schwan
[illegible] OF HEATING POTENTIAL INSIDE LOSSY SPHERES
Int. J. Radiat. Biol. Exp., Vol. 22, No. 6, pp. 457-463 (1975)

[illegible] and K.-M. Chen
HEATING OF SPHERICAL MODELS RESEMBLING HUMAN AND INFRAHUMAN HEADS BY ELECTROMAGNETIC WAVES
0048-6604/79/1112-S009, Radio Sci., Vol. 14, No. 6S, pp. 51-62 (1979)

Analyses under

[illegible] PHYSICAL METHODS/DOSIMETRY

Hagmann, M. J. and O. P. Gandhi
NUMERICAL CALCULATION OF ELCTROMAGNETIC ENERGY DEPOSITION IN MODELS OF MAN WITH GROUNDING AND REFLECTOR EFFECTS
0048-6604/79/1112-S005, Radio Sci., Vol. 14, No. 6S, pp. 23-29 (1979)
Study type: (16) Physical methods/dosimetry; BLOCK MODELS; HUMAN
Effect type: Theoretical calculations of RFR energy-absorption distributions in humans near ground and other reflectors
Frequency/wavelength: 10 MHz to 1 GHz
Modulation: Presumably CW
Power Densities: Not applicable
SAR: See results
Exposure conditions: Not experimental
AUTHOR ABSTRACT: Image tneory has been used to obtain moment-method sclutions of the deposition of electromagnetic energy in standard man as a function of grounding and reflector effects. The calculated values are in good agreement with experimental data. For the electric vector parallel to the long axis of the body, the resonant frequency of standard man snifts from 77 MHz in free space to 47 MHz when standing on a ground plane. The dependence of reflector effects on spacing and frequency are in agreement with the gain enhancement calculated for dipoles by antenna theory.
OTHER INFORMATION: The Hagmann et al. (1979) homogeneous, 180-cell block model of the "standard" man was used in conjunction with either a ground plane or one or more reflectors, all of which were assumed to be infinite and perfectly conducting. For calculations, these planes were replaced with appropriately located images of the model. For the model in conductive contact with the ground plane, the whole-body resonance is at 47 MHz at which the average SAR is 32.5 percent higher than at 77 MHz, the resonance in the absence of the ground plane. Part-body resonances are also evident, with the effect greatest in the legs and neck and least in the head. However, such ground-plane effects are largely eliminated if conductive contact with the ground is removed. In the presence of reflectors, the whole-body SAR depends on the spacing in wavelengths of the body from the reflectors. In general, the whole-body SARs are enhanced by about the same amount as the ratio of the effective area of a dipole in the presence of such reflectors to the area in their absence, but the values for the model show a pronounced roll-off at higher frequencies than the corresponding values for a thin dipole of the same length, presumably because of the lateral extent of the model. However, the relative distribution of SAR within the model is not greatly affected by the presence of such reflectors. The authors also mention that for certain combinations of length and width of reflecting

sheets, a finite corner reflector may exhibit far higher gain (supergain) than a similar reflector of infinite extent.
FINAL CRITIQUE: The results of this theoretical study are interesting as far as they go. However, their applicability to investigations of bioeffects of RFR appear to be limited to very few if any realistic exposure situations, not only because of the assumption of infinite, perfectly conducting planes, but also because of the sensitivity of the results to the distance of the model (in wavelengths) from such planes. For example, significant whole-body SAR enhancement would occur primarily if a subject is fortuitously located relative to a corner reflector or is in conductive contact with a highly conductive region of the ground. The authors also state that effects of finite conductivity have not been treated yet.
REFERENCES: 0018-9480/79/0900-0804, Hagmann, M. J., O. P. Gandhi, and C. H. Durney, NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION FOR A REALISTIC MODEL OF MAN, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 804-809 (1979)

Hagmann, M. J., O. P. Gandhi, and C. H. Durney
NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION FOR A REALISTIC MODEL OF MAN
0018-9480/79/0900-0804, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 804-809 (1979)
Study type: (16) Physical methods/dosimetry; BLOCK MODEL; HUMAN
Effect type: Calculations of whole-body SAR and SAR distributions in a block model of man
Frequency/wavelength: 10 to 600 MHz
Modulation: CW tacitly assumed
Power Densities: Not relevant
SAR: Various whole-body and distributed SARs cited
Exposure conditions: Electric vector parallel to the long (symmetric) axis of the model and propagation from front to back
AUTHOR ABSTRACT: Numerical calculations of absorbed energy deposition have been made for a block model of man that is defined with careful attention given to the biometric and anatomical features of a human being. Calculated post-resonant absorption and distribution of energy deposition through the body have better agreement with experimental results than previous calculations made using less realistic models.
OTHER INFORMATION: The authors used a total of 180 cubical cells of various sizes to obtain a best fit to the contour of the "standard" man (1.75 m high). They assumed a symmetry plane between the left and right sides to reduce the number of cells needed for calculations to 90, pointing out that the solutions are only applicable for incident fields in which both the electric and propagation vectors are in the symmetry plane. The complex permittivity was assumed to be homogeneous within each cell, and the volume-weighted value for each cell was determined from tissue properties reported in the literature. Unlike previous block-model solutions, which had energy-deposition differences between adjacent cells as high as 239:1 (at 10 MHz) and thereby rendered the cell-homogeneity assumption questionable, the present model yielded a maximal ratio of 8:1. The whole-body SAR values obtained for the region below resonance are within 10 percent of those calculated for prolate-spheroidal and ellipsoidal models, and also show the 1/f dependence found experimentally. However, the block models permit far more accurate calculations of SAR distributions.
FINAL CRITIQUE: This paper is a representative example of a number of papers by these and other investigators on the subject of theoretical calculations of whole-body SAR and internal SAR distributions, showing the significant progress being made in relating energy absorption rates to incident power densities. Excellent reviews of the subject are given by

Durney (1980) and Gandhi (1980). However, these treatments yield numerical data only on energy-absorption distributions, and not on actual temperature distributions that would occur for in-vivo exposures, because the analyses do not account for heat removal mechanisms such as by blood circulation.

REFERENCES: 0018-9219/80/0100-0033, Durney, C. H., ELECTROMAGNETIC DOSIMETRY FOR MODELS OF HUMANS AND ANIMALS: A REVIEW OF THEORETICAL AND NUMERICAL TECHNIQUES, Proc. IEEE, Vol. 68, No. 1, pp. 33-40 (1980)
0018-9219/80/0100-0024, Gandhi, O. P., STATE OF THE KNOWLEDGE FOR ELECTROMAGNETIC ABSORBED DOSE IN MAN AND ANIMALS, Proc. IEEE, Vol. 68, No. 1, pp. 24-32 (1980)

Hagmann, M. J., O. P. Gandhi, J. A. D'Andrea, and I. Chatterjee
HEAD RESONANCE: NUMERICAL SOLUTION AND EXPERIMENTAL RESULTS
0018-9480/79/0900-0809, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 809-813 (1979)
Study type: (16) Physical methods/dosimetry; BLOCK MODEL OF HUMAN; IN-VIVO RAT
Effect type: Theoretical and experimental determinations of SARs for attached and isolated heads
Frequency/wavelength: Experimental: 2.45 GHz
Modulation: Presumably CW
Power Densities: Up to 100 mW/cm.2
SAR: See results
Exposure conditions: Models of various preselected sizes were exposed at 2.45 GHz, and scaling was applied to the results, to obtain values of SAR versus frequency for full-scale models.
AUTHOR ABSTRACT: We have used numerical solutions and experiments with phantom models of man, and experiments with the Long Evans rat to show the existence of head resonance. Greatest absorption in the head region of man occurs at a frequency of about 325 MHz. Absorption is stronger for wave propagation from head to toe than it is when the electric field is parallel to the long axis. The highest absorption cross section for the human head is predicted to be approximately 3.5 times its physical cross section.
OTHER INFORMATION: The Hagmann et al. (1979) block model of the "standard" man was modified to increase the number of cells in the head from 12 to 144 and from 4 to 32 in the neck region. For front-to-back propagation with the electric vector parallel to the long axis, the calculations show a head resonance at about 350 MHz, at which the average SAR for the head is about 0.12 W/kg per mW/cm.2 and that of the whole body about 0.05. At 450 MHz, the head SAR is about 0.10, so this head resonance is relatively broad. A sharper head resonance at 375 MHz was obtained for head-to-toe propagation. At this frequency, the head SAR is about 0.17 W/kg per mW/cm.2 and that of the whole body about 0.07. Experimental measurements were performed at 2.45 GHz with homogeneous figurines having lengths of 20.3, 25.4, 33.0, and 40.6 cm, corresponding to scaled frequencies of 284.5, 355.6, 462.3, and 567.0 MHz, respectively. Whole-body average SARs and those of the detached head were measured with a calorimeter. The authors state that the experimental results for head-to-toe propagation were in good agreement with the calculated values, which appears true for the plotted whole-body results. However, the experimental value of head SAR at 355.6 MHz (closest to the theoretical resonance) appears to be considerably lower than the calculated value. Whole-body and head SARs were also measured calorimetrically at 2.45 GHz for freshly killed rats. The authors state that head resonance is more pronounced for head-to-tail than for broadside

propagation, but the SAR data cited are for 2.45 GHz only, not for a range of frequencies necessary to reveal a peak. They also measured colonic and brain temperatures in anesthetized rats (at 2.45 GHz), and found that the ratio of head-to-whole-body heat content for the anesthetized rat is smaller than for the dead rat, and ascribe this finding to blood circulation in the former.

FINAL CRITIQUE: As stated by the authors, the calculated resonance at 375 MHz of the attached human head for head-to-toe propagation is lower than the 450 MHz value calculated by Joines and Spiegel (1974) for the 10-cm multilayered spherical model of the isolated head. However, their experimental corroboration is not as strong as they imply. Specifically, examination of their four experimental points shows that the resonant frequency is somewhere between 400 and 450 MHz, and it is difficult to estimate the average SAR at this frequency. Thus, their conclusion that energy absorption in the head is strongly dependent on the presence of the rest of the body, though probably true, is weakened. Although such studies of head resonances based on averaged SARs are useful, the calculated SAR distributions within the head, which are not discussed, would be of greater significance with regard to possible RFR bioeffects. In this context, see for example, Rukspollmuang and Cheng (1979). Regarding the experimental work with rats, the results are too few in number to permit any conclusions that were not known or surmised from prior work.

REFERENCES: 0018-9480/79/0900-0804, Hagmann, M. J., O. P. Gandhi, and C. H. Durney, NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION FOR A REALISTIC MODEL OF MAN, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 804-809 (1979)

Joines, W. T. and R. J. Spiegel, RESONANCE ABSORPTION OF MICROWAVES BY THE HUMAN SKULL, IEEE Trans. Biomed. Eng., Vol. 21, No. 1, pp. 46-48 (1974)

0048-6604/79/1112-S009, Rukspollmuang, S. and K.-M. Chen, HEATING OF SPHERICAL VERSUS REALISTIC MODELS OF HUMAN AND INFRAHUMAN HEADS BY ELECTROMAGNETIC WAVES, Radio Sci., Vol. 14, No. 6S, pp. 51-62 (1979)

Kritikos, H. N. and H. P. Schwan
FORMATION OF HOT SPOTS IN MULTILAYER SPHERES
IEEE Trans. Biomed. Eng., Vol. 22, pp. 168-172 (1976)
Study type: (16) Physical methods/dosimetry; SPHERICAL MODELS; HUMAN
Effect type: SAR distributions in multilayer spherical models of the human head
Frequency/wavelength: About 50 MHz to 10 GHz
Modulation: Assumed CW
Power Densities: Not relevant
SAR: See results
Exposure conditions: Not experimental
AUTHOR ABSTRACT: A theoretical study of the distribution of the normalized heating potential resulting from a plane wave incident in a multilayered sphere simulating a human head with skin, fat, bone, and brain tissue layers has been undertaken. It was found that for spheres of radii 10 cm and 5 cm a relative peak of the normalized heating potential occurs in the vicinity of the center of the sphere. For the case of the 5 cm sphere in the range of frequencies 400 MHz to 2.76 GHz the maximum value of the heating potential occurs at the center suggesting the possibility of a hot spot. A comparison between the multilayer and a single layer model shows that the maximum values of the heating potential are the same.
OTHER INFORMATION: The model treated in this paper is a refinement of the homogeneous sphere analyzed previously by these investigators (Kritikos and Schwan, 1975). It consists of concentric spherical layers having thicknesses and the dielectric constant and electrical conductivity values approximating those for the skin, subcutaneous fat, skull, and brain of a human. As in the previous paper, the authors present their results in terms of the "normalized differential absorption cross section," delta-S, which they define as the power absorbed per unit volume (W/cm.3) per unit of incident power density (W/cm.2), which is equivalent to the SAR if the density of all tissues is taken as 1 g/cm.3. For the 10-cm-radius multilayer sphere, delta-S is highest at the surface, on the axis pointing toward the source, for all frequencies, and for the 5-cm sphere, the maximum delta-S occurs within the sphere ("hot spot") but only within the frequency range from about 400 MHz to 2.76 GHz. These results are consonant with the general treatment of the homogeneous sphere in the previous paper, with only minor differences in internal distributions of delta-S between the two models. Again the authors indicate that the "hot spot" results for the 5-cm sphere are pertinent to heads of human infants, and they emphasize that actual temperature rises would be lower than delta-S values because of heat removal mechanisms not included in their calculations. The authors also provide a brief review

of the results of other theoretical treatments of homogeneous and multilayered plane and spherical models of various radii for various frequencies.

FINAL CRITIQUE: As is true for the previous paper, the results are significant qualitatively and also quantitatively to the extent that the multilayer sphere models the structure and constituents of actual heads. However, because heat removal mechanisms are not accounted for in these treatments, the numerical results are not applicable to in-vivo exposure situations.

REFERENCES: Kritikos, H. N. and H. P. Schwan, THE DISTRIBUTION OF HEATING POTENTIAL INSIDE LOSSY SPHERES, IEEE Trans. Biomed. Eng., Vol. 22, No. 6, pp. 457-463 (1975)

Kritikos, H. N. [illegible]
THE DISTRIBUTION OF [illegible] Y SPHERES
IEEE Trans. [illegible] 4 P463 (1975)
Study type: [illegible] PHERICAL
MODELS; HUMAN
Effect type: SAR [illegible] theoretical models
of the human head
Frequency/wavelength: [illegible]
Modulation: Assumed CW
Power Densities: Not [illegible]
SAR: See results
Exposure conditions: [illegible]
AUTHOR ABSTRACT: The [illegible] potential
inside a lossy sphere [illegible]
character[illegible] [illegible]ated in
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OTHER INFORMATION: [illegible]
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to SAR [illegible] [illegible] W/cm.3.
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of the sma[illegible] [illegible]urs at
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convergence of [illegible] well
beyond its [illegible] [illegible]ate ratios
both larger and [illegible] [illegible]urs within
the sphere [illegible] [illegible]mance, but
only for [illegible] [illegible] the abstract.
Thus, they [illegible] [illegible] would be
pertinent [illegible] [illegible]nts. They
also emphasize that [illegible] [illegible]not actual

temperature rises, which would be lower because of heat diffusion and heat convection due to blood flow.

FINAL CRITIQUE: This is a representative theoretical paper dealing with the important subject of internal regions of maximum RFR energy absorption ("hot spots") in the head. A later paper by these authors (Kritikos and Schwan, 1976) describes the results for a multilayered spherical model. Such results are significant qualitatively, and also quantitatively to the extent that these models simulate the structures and internal constituents of actual heads. More recent theoretical treatments of SAR distributions in the isolated and attached head, based on so-called block models, are given by Rukspollmuang and Chen (1979) and Hagmann et al. (1979), respectively. However, none of these treatments account for modifications due to the presence of heat-removal mechanisms, so the numerical results are not applicable to in-vivo exposure situations.

REFERENCES: 0018-9480/79/0900-0809, Hagmann, M. J., O. P. Gandhi, J. A. D'Andrea, and I. Chatterjee, HEAD RESONANCE: NUMERICAL SOLUTIONS AND EXPERIMENTAL RESULTS, IEEE Trans. Microwave Theory and Tech., Vol. 27, No. 9, pp. 809-813 (1979)

Kritikos, H. N. and H. P. Schwan, FORMATION OF HOT SPOTS IN MULTILAYER SPHERES, IEEE Trans. Biomed. Eng., Vol. 22, pp. 168-172 (1976)

0048-6604/79/1112-S009, Rukspollmuang, S. and K.-M. Chen, HEATING OF SPHERICAL VERSUS REALISTIC MODELS OF HUMAN AND INFRAHUMAN HEADS BY ELECTROMAGNETIC WAVES, Radio Sci., Vol. 14, No. 6S, pp. 51-62 (1979)

R[illegible]
[illegible]HUMAN AND
INFRA[illegible]
0048-66[illegible], N. 59, pp. 51-62
(1979)
Study type: [illegible] BLOCK MODELS;
HUMAN
Effect type: [illegible] energy absorption
distribution [illegible]
Frequency [illegible]
Modulation [illegible]
Power Density [illegible]
SAR: [illegible]
Exposure conditions [illegible]
AUTHOR ABSTRACT: [illegible] Fredholm integral
equation [illegible] EM heating
in realistic [illegible]. The head
consists [illegible] that are
surrounded by [illegible] has also
been used to [illegible] spherical
models of [illegible] the EM
heating [illegible] is lower
than that [illegible] the
bony structure [illegible] the
brain, [illegible]
OTHER INFORMATION: [illegible] the head
with small [illegible] integral equation
to calculate [illegible]
incident [illegible] results for 3
and 7 cm [illegible] cells
per eight [illegible] the exact
Mie theory [illegible] 60-cell
smaller [illegible] for the Mie
theory [illegible] head at
918 MHz, [illegible] with the
Mie theory [illegible] poor results
were obtained [illegible]
improvement [illegible] model. The results
were not [illegible] use of a cell
size comparable [illegible] necessary.
The paper [illegible] cells in which
the head consists [illegible] shape," two
eyes, and a [illegible] which is given
appropriate [illegible] and conductivity.
Similar calculations [illegible] for models in which
the skull structure [illegible] head with frontal
dimensions of 18 cm [illegible] deep, high
internal [illegible] at 918 MHz (near
resonance [illegible] peak in the brain

and eye regions were low compared to the rate in the bony structure. With the latter absent, the absorption rate in the brain was about 43 percent higher. The results at 2450 MHz indicate that maximum absorption occurs near the proximal surface, with relatively little absorption in the brain. The authors also note that absorption in the eye regions is relatively low, even though the eyes are near the proximal surface, because of the presence of the surrounding bone region. Qualitatively similar results were obtained at 2450 MHz for an animal head model having half the dimensions cited above.

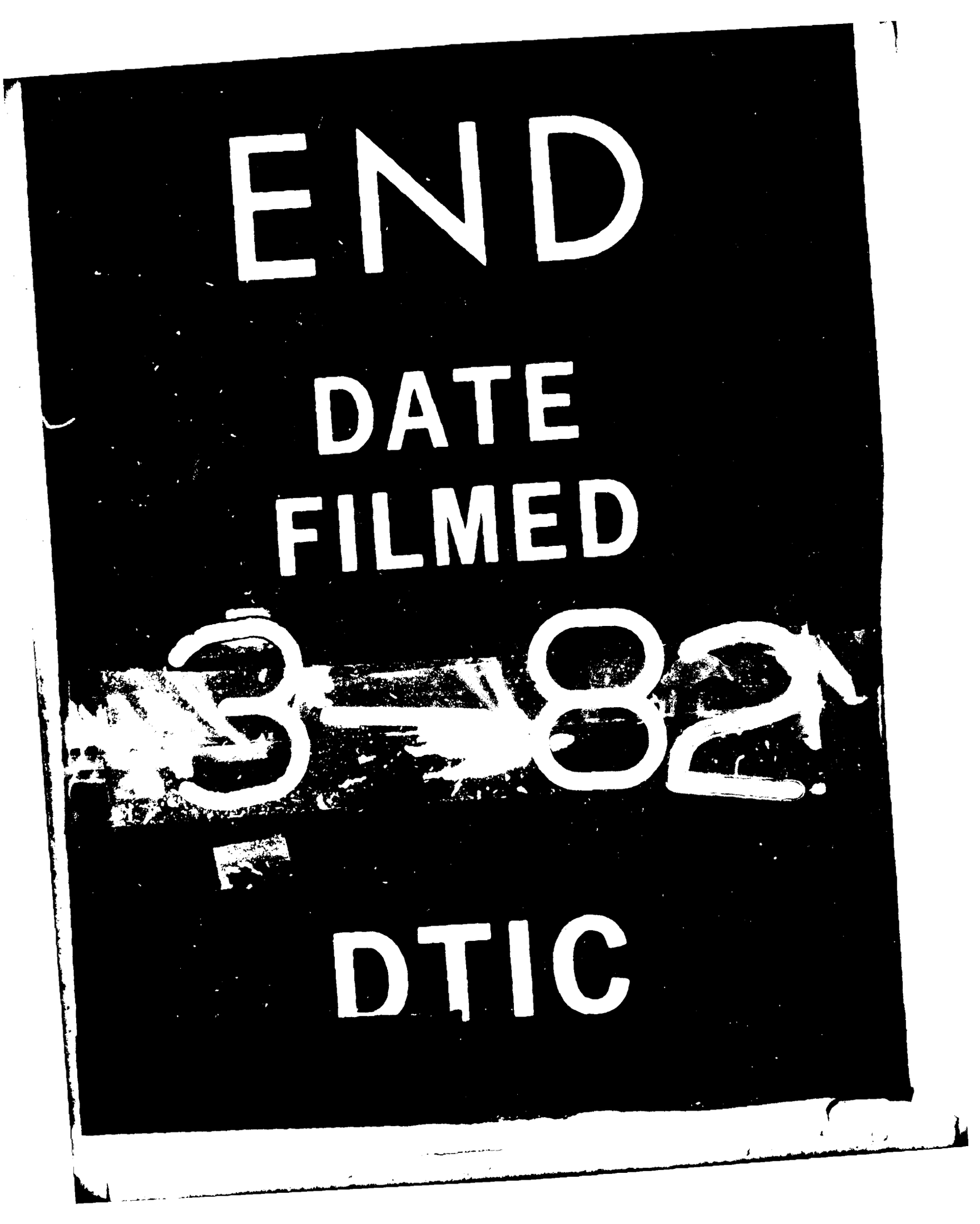
FINAL CRITIQUE: The results for the spherical block models are qualitatively consistent with those obtained for multilayered spherical models, e.g., those of Kritikos and Schwan (1976), including the displacement of the region of maximum energy absorption toward the front surface as the frequency is increased. However, as implied by the authors, the utility of the basic approach is dependent on the use of cube sizes that are comparable to, or smaller than, the skin depth. The major contribution of this paper is the use of the block approach on inhomogeneous head models having contours and internal structures that correspond more closely to actual heads than spherical models. Especially interesting are the results indicating that the absorption rates are significantly higher in the bone structures than in the brain and eye regions, implying that the skull tends to shield the brain and eyes to a considerable extent, at least for the two frequencies studied. Experimental verification of these results would be most useful.

REFERENCES: Kritikos, H. N., and H. P. Schwan, FORMATION OF HOT SPOTS IN MULTILAYER SPHERES, IEEE Trans. Biomed. Eng., Vol. 22, pp. 168-172 (1976)

(18) DRUG INTERACTIONS

List of Analyses

Chou, C.-K., A. W. Guy, J. B. McDougall, and L.-F. Han
EFFECTS OF CONTINUOUS AND PULSED CHRONIC MICROWAVE EXPOSURE ON RABBITS
In ABSTRACTS OF OPEN SYMPOSIUM ON THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC WAVES, Helsinki, Finland (1978) (See "Nervous System (EEG and EP)" for analysis.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